HANDBOOK FOR SCIENCE TEACHERS IN SECONDARY MODERN SCHOOLS

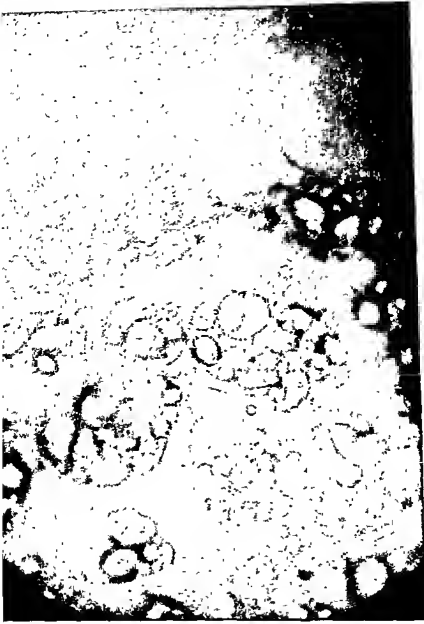

PLATE I. Starch grains in a section of potato, taken with the type of apparatus drawn on page 82.

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PREFACE

This book is intended as a guide to the Science Teacher in a Secondary Modern School. I have written it because I feel that there is a need for a book of this kind. Many text books have been written for such Schools, but these in themselves are not guides for the teacher. There is the syllabus to consider. Since children in a Secondary Modern School do not sit for external examinations, there is no examination syllabus to form a basis for a scheme, and the syllabus has to be worked out *from first principles*.

Then there is the means of putting the syllabus into effect. This introduces questions of method. The broader issues are determined by laboratory facilities and size of classes, but more detailed arrangements involve a consideration of equipment including apparatus, chemicals, and books.

The learning of science by the children in the Secondary Modern School *should not be restricted to lesson periods.* It is necessary to consider a School Scientific Society and Library facilities. A chapter has been added on the use of Visual Aids.

It is not possible to write a book of this type without help of many kinds. Although what I have written is largely the result of personal experience this has been built up through contact with many people who have in a measure contributed to my experience.

I am particularly grateful to the Science Masters' Association for the help I have gained from their excellent list of *Science Books for a School Library* in compiling my list at the end of Chapter Eleven. The plans of laboratories are reproduced with due acknowledgement to the Essex Education Authority. I wish to express my thanks to J. B. Lippincott Co. of Chicago for fig. 1 adapted from, "Physics for the New Age" by R. H. Carleton and H. H. Williams; to the Editor of the *Journal of Animal Ecology* for fig. 4 adapted from the illustration in the paper by N. Haarlov entitled, "A new Modification of the Tullgren Apparatus" (J. Anim. Ecol. 16); to the Editor of *Nature* for permission to include the

graph in fig. 22; to The Clarendon Press, Oxford for fig. 28 adapted from, "Plant Life Forms" by C. Raunkiaer (translated by H. Gilbert-Carter); to the University of London Press for fig. 29 adapted from "Handbook of Botanical Diagrams" by Blodwen Lloyd; to Ginn and Co. of Boston, Massachusetts for Plate II adapted from, "The Plant Kingdom" by W. H. Brown; and to Chapman and Hall Ltd., for the details of the specific gravities of salt solutions (Table 1) from, "The Potato" by W. G. Burton. My late science students at Oakley Training College, Cheltenham have helped to provide material for the book.

My grateful thanks are also due to my wife and Mr L. Saunders for typing the MSS. I also desire to acknowledge my gratitude to Mr D. Paige who helped with the line drawings, and to Mr J. N. Britton and the House of John Murray for the care and trouble taken in producing the book.

As an officer of a local authority, I desire to state that the views expressed in this book are entirely my own.

GORDON NUNN

NOTE REGARDING LIST OF LIBRARY BOOKS (pp. 157–193)

A number of the books in this list are now out of print, and a great many of the prices have now been changed. Nevertheless the list has been reprinted in its original form, since (a) out-of-print items can frequently be obtained second-hand; (b) the prices give a fair indication of the size and scope of each work; and (c) an admirable supplement and corrective —though confined to books currently available—will shortly be at hand in the new edition (Autumn, 1956) of the S.M.A.'s *Science Books for a School Library* (John Murray).

CHAPTER ONE

THE PLACE AND VALUE OF SCIENCE IN THE CURRICULUM

"Then felt I like some watcher of the skies when a new planet swims into his ken."[1]

A. Science as a Background Subject

Science appeared on the time-tables of all the Secondary Modern Schools I have seen, and it is reasonable to suppose that it will as a general rule appear in the curriculum of all such schools. The question as to why it is there does not appear to be always clear. Some schools do not include French in their curriculum, but why, for example, should Science be preferred to French?

As a subject, Science can be placed on the time-table for two main reasons. The first is to have it included because it is felt that Science should be in the background of the minds of all civilised individuals; it should be part of their mental make-up. To put it briefly, let us consider it a "background subject".

In this capacity the learning of science in the Secondary Modern School should perform four functions.

The first function is the inculcating of the Spirit of Science. This, in my opinion is the most important function. To some people the suggestion of a Spirit of Science may sound ethereal or even psychological. It is probably both of these and more. After Isaac Newton had achieved fame, he is reported as having said, when gracious homage was paid to his great discoveries, that he felt like a child playing on a pebbly shore. Every now and again the child finds a prettier pebble than its fellows which he picks out and places on one side. Newton likened the finding of a prettier pebble to a scientific discovery. There is something in the Scientific Spirit which savours of glorious adventure. After all it is the search after Truth which the Philosophers from the time of

Plato have considered at least equivalent to the searches after Goodness and Beauty.

The search after Truth is an effort to understand the world factually. To understand something factually does not make such a pursuit materialistic, for in putting together this jig-saw we discover something of nature's mystic methods. We who have a strong sense of the Spiritual say that we see something of God's purpose in Nature by the scientific pursuit of Truth.

Basing truth on facts has a disciplinary value which only those who have carried out scientific research can appreciate fully. Scientific discovery in many cases begins with speculation. You get a "hunch" and then you proceed to find out if your "hunch" is correct. Often you discover that facts show it to be false. But in carrying out this work you may discover by accident something that is true.

Let me quote a personal case. In carrying out research on the Vitamin C content of potatoes, we thought at one time that small potatoes had a higher concentration of this vitamin than large potatoes. After examining a dozen potatoes this appeared to be true, but after testing 100 potatoes it was shown to be false. However, in the course of the work we discovered that depreciation of Vitamin C in potatoes during storage is related to the humidity of the atmosphere during this period.[2]

Another great value of the Scientific Spirit is the humility which it engenders. Before the intricacies of nature, the genuine scientist becomes very humble. If you read the history of Michael Faraday or preferably his own writings, you will notice how humility is a very great part of his character. One example of his humility is the way in which he refused to have honours bestowed upon him by Queen Victoria.

The second function is training children in Scientific Method. Since this subject will be treated more fully under Method, I will only write briefly here. Science without scientific method is not truly science, because it is in the very nature of Science that it has been built up by following certain well-defined methods.

First of all data must be obtained. Now for data to be obtained certain matters must be observed. Scientific observation is of great importance for it provides the facts on which scientific reasoning is based.

Observation can be done directly by seeing, hearing, feeling, tasting, smelling or exercising one of the other senses some psychologists say we possess.[a] In these days, however, scientific observation is usually not quite so simple.

The senses can be magnified by using such instruments as microphones, microscopes and telescopes. Or observation can be made more accurate by measurement with all kinds of instruments from simple rulers to such complicated devices as *p*H meters, cathetometers, spectrometers and spherometers. Or again tests can be carried out to bring to our observation matters which cannot be sensed otherwise. Common tests of this kind are chemical and electrical.

In reaching conclusions from the data obtained by observation the argument has to proceed by well-defined stages.

To begin with, we must be sure of our data. This not only involves accuracy on our part, but also in the instruments we use. Data cannot be more accurate than our instruments and our powers will allow. Then again we must be sure that we are measuring what we intend to measure. A scientific tyro may sow cabbage seed each year in the same plot of ground and measure the average yield per seed each season. He may deduce that the difference in yield varies according to the rainfall without considering such factors as the varying fertility of the soil, diseases of brassicas and pests.

Consequently in considering data, a scientist must consider all the factors that may have contributed to the data. His knowledge and experience may not provide him with all of them. Not only should he know all the factors but he must also know the varying powers of their influence. It is a rule of scientific procedure that if you experiment you must only change one factor at a time. Then when you get a change in result you can usually tell which factor has caused it.

In biological work this is much more difficult because the life-factor comes in. The work I have been carrying out in the Vitamin C content of potatoes has shown that the

concentration of this vitamin varies more as between potatoes of the same variety than between potatoes of different varieties. In order to arrive at conclusions regarding the average Vitamin C content of different varieties, on lifting it is necessary to test at least two dozen potatoes of each variety grown under similar conditions of soil, manuring, mechanical treatment and during the same season. Potatoes possess individuality like all other living things. It is for this reason that statistical analysis has such a fundamental part in biological research.

When the data has been accumulated in such quantity and quality as to justify reasoning, the next stage of Scientific Method comes into play.

There are three chief methods of reasoning: Deductive, Inductive and Analogical. The main point is that the reasoning must be logical. It is important to have correct facts; it is equally important to reason carefully.

As a result of this reasoning, the scientist arrives at conclusions. They may be positive in that he discovers something new or may be negative which in their turn disprove some theory. Although the negative result is not so startling as the positive, it is, nevertheless, important. In this last stage there are subtle snares, for since scientists are human, they like to find conclusions they expect. They like to be able to prove some pet theory, but if data and reasoning show the theory to be untenable they must, if they are true scientists, gracefully admit that their theory has been discounted. Children "cooking" results in a laboratory when determining the equivalent of magnesium are not doing anything very strange; adults are just as prone to this kind of juggling.

The next aim is to give children an understanding of nature and man's use of nature. Let us first consider nature, so far as we can, as if it were uninfluenced by man. In our own country it is not easy to draw the line, but we can say that the heavens, the seas, most of the coast, the mountains, the bogs and marshes, many of the rivers, lakes and ponds and rock faces as well as the interior of the earth are largely natural. In addition to these regions we have the plants and animals that are indigenous to them. The heavens largely

form the basis of the study of Astronomy and Meteorology. The latter has the distinction of being the science which man makes a great deal of use of, but can do little to alter. The structure of the earth's interior largely concerns Geology. The pattern of the plant and animal life is called Ecology. It is desirable that children should have some knowledge of all this. It is, in fact, the natural environment in which they live.

The second part of the study, is man's use of nature. Now the child's own body seems to come in between the two; it has arisen through the natural forces of evolution, but it is also influenced by man's use of nature and is the *raison d'être* for man influencing nature. The science curriculum can be likened to an arch. In many ways, the study of the human body should be the keystone of any general science course. You can consider the natural world as being on one side of the arch, and man's effect on nature as the other side of the arch.

Man's use of nature is a vast subject. Even the face of the countryside has been largely altered by man, by farming, building, road-making, sport, the spoils of industry and in many other ways. From the point of view of a general science course we have such subjects as the chemicals which man has produced, and their uses; the metals he has produced from raw materials; the production of pure water, gas and electricity and their uses; the disposal of waste and the production of materials for his use.

The last point which concerns the value of Science as a Background Subject is that concerned with learning the facts of science. On this matter there has been a good deal of controversy. Science in Grammar schools has been to a large extent concerned with children learning facts in order to pass the first and second official school examinations. This kind of memorisation has persisted also in the University.

It is desirable to train the memory, but surely not by learning facts which are often of little use. Some few facts may be essential as tools in life, but it is really more important to know how to ascertain facts quickly than it is to remember them. It is here where the training in the use of a library is important.

A teacher of Science will find it useful to draw up a list of facts which he thinks children should know on leaving school. The list can be shortened for C and D children by careful selection. Since opinions should differ regarding what are essential facts I do not propose to include my list. Like the Syllabus itself, the list does depend to some extent on the school and its environment.

Just allow me to mention another point about learning facts. Recently I carried out tests in different types of schools in varying localities with "14 plus" children. Children in Grammar Schools only did better in these tests in the subjects in which they were examined in the School Certificate Examination. The children in a school in one of the dock areas of London knew more about the colours of wild flowers than the children in a country school in the heart of Gloucestershire!

B. Science as a Subject providing a Basis of Specific Knowledge and Method

The second reason for placing Science on the time-table is as a specific subject. This is not often done in the Secondary Modern School, which I feel is a weakness. The Secondary Modern School should provide a common curriculum for the children up to 13 years of age. At 13, the children should have a choice of courses according to circumstances. Such courses as Nursing, Domestic Science, Commercial, Industrial, and Agricultural might be arranged. I know that often staffing and buildings do not allow this kind of arrangement, but if the Secondary Modern School is to justify its place in the scheme of Education, this is one way in which it should develop.

A child opting to take the Commercial course would continue to take "General Science" as a background subject, but a child taking Nursing, Domestic Science, Industrial or Agricultural courses would take Science as a special subject. This is a vocational aspect; in the case of Nursing, the science would be based on The Human Body; in the case of Domestic Science it would be based on The Human Body,

Food and Nutrition, Cleaning and General Household Management. In the case of the Industrial course, the science would depend on the industrial environment, which might suggest such subjects as Mechanics, Electricity, Chemistry or Biochemistry. Agriculture would suggest a science made up of Biology and Rural Science.

There is also the child to consider who is interested in science as a hobby. It is likely that he will in any case follow one of the courses I have mentioned. The Scientific Society will give this child the extra scope he needs.

C. The Social Value of Science

Now that many Secondary Modern Schools are organising courses in social studies, it is worthy of consideration to include in these studies something of the history of science. Teachers do not always discriminate between carrying out scientific work and reading or talking about scientific work.

To provide an example, to give a lesson on Michael Faraday without any demonstrations of the experiments he carried out is not in itself justified in the Science curriculum of a Secondary Modern School. In the Science lesson the children can see a demonstration of some of Faraday's experiments, for example on electrolysis and on electromagnetic induction. They should also be able to carry out some for themselves. In the Social Studies group of subjects Michael Faraday can also appear.

In this group of subjects, he will be considered in relation to his own time and our own time. With reference to his own time it can be shown how he became famous rising in his scientific career from a laboratory assistant at the Royal Institution to the Director of that august place. The impact of his contributions to science was not felt until some time later, till many years after his death in fact.

In the Social Studies group of subjects which, by the way, is often taken instead of History and Geography, the historical development of science is seen in its relation to contemporary and later events. It is not only such epoch-making inventions as the steam engine, the internal combustion

engine, antiseptics, anaesthetics, the production of nitrogen oxides from the electrical sparking of the air, and atomic fission which have altered the shape of events, but also the many minor discoveries which have made their contribution to the pattern of civilisation.

It is good to see the development of social studies in schools, for here is a splendid opportunity to interweave the various strands of historical development. This provides a great opportunity to reveal the cultural value of science.

Summary

A. Science as a Background Subject.
   1. Place in the curriculum.
   2. Value.
      (a) Inculcating the Spirit of Science.
      (b) Training the children in Scientific Method.
      (c) Giving children an understanding of Nature and man's use of Nature.
      (d) Learning some of the important facts of Science.

B. Science as a subject providing a basis of specific knowledge and method in the case of those children who:
   1. Are interested in Science for its own value; and
   2. Are interested in Science from the point of view of a career.

C. The Social Value of Science.

References (Chapter One)

[1] Keats, *On first looking into Chapman's Homer*.

[2] F. Wokes and C. Nunn, "Vitamin C in Potatoes", *Nature*, *162*, 900, 901, 1948.

[3] H. D. Renner, *The Origin of Food Habits* (Faber and Faber). 151.

CHAPTER TWO

CONTENT

A. The Background Science

From experience I have found that the general science course in a Secondary Modern School is best based on topics. The topics which suggest themselves are The Home, Transport, Hobbies, The Workshop, Health and the Human Body, The Garden, The Farm, and The Countryside. These seem to be the more obvious subjects. They are all concerned with the child and his environment.

1. The Home

Under this heading we might choose such topics as Water, Gas and Electricity being the three utility services associated with most houses. To these we might add as separate topics the telephone and the wireless, which although developments of electricity, might well be treated separately.

Water has to be supplied to the House so the question of supply naturally arises. What is the source of the supply, is it a river, an artesian well or a reservoir situated in the hills? How is the water treated so as to be fit for use in the home? It is here where a visit to the Water Works is indicated.[1] Here the children can see the difference between "raw" and "pure water"! By means of a microscope they may be able to see bacteria in the "raw" water or cultures made from such samples. There may be algae in the water such as star-shaped diatoms. At the Water Works the children will learn the methods of treatment before filtering, a treatment designed to free the water of impurities, particularly the dangerous ones.

The filter beds will prove interesting. Children should learn something of the flora and fauna which can arise on filter beds. There is a particularly good film called "The Filter"[2] which can be used to illustrate this point.

When the children have visited the Water Works they may

like to construct a model of the Water Works. It is also helpful for them to bring back to school samples of the water after the various treatments.

How the water reaches the home is the next question. It may be that the reservoir, which is the source of the water, is situated in the hills much higher than the house. Water will flow downhill, but it will also flow uphill so long as it is in a closed pipe and the end of the pipe is below the level of the water in the reservoir. The Romans did not know this; that was why they built aqueducts to carry water across valleys in pipes.

In some districts the water has to be pumped up to a subsidiary reservoir above the particular town or village. This is a useful way of introducing the subject of pumps. Liquid pressure can also be brought into the scheme at this stage.

When the water reaches the house it enters the household system. Children should become familiar with this and compare it with the school system. This brings in convection, conduction and radiation of heat.

Then there are the uses of water in the home. Water is used for cleaning purposes; for washing ourselves, our clothes and our utensils, for flushing the W.C. and for cleansing drains. All these introduce other topics.

Washing ourselves and our clothes suggests soap. Soap can be made in the laboratory from rancid fat. The manufacture of soap can now be considered. Children may be able to visit a soap works. In connection with this subject, surface tension can be dealt with for the purpose of soap is largely to increase the wetting property of water.

This leads to the subjects of soft and hard water. The two kinds of water can be compared particularly in their action on soap. A differentiation should be made between temporary and permanent hardness. Methods of treating hard water may be outlined.

Synthetic detergents can also be considered. These are in many ways superseding soap because they have certain advantages over soap, e.g. they do not require fat and also they are unaffected by hard water.

The use of the water for flushing W.C.s and drains leads

on to a subject which has tended to be neglected in schools, viz. sewage disposal.[3] It is important that the waste materials eliminated from human beings should not be wasted.[4] Particularly in so far as they are so rich in nitrogen they have a high fertility value for soils.

There are also industrial wastes to consider. Some of these are useful, such as the fibrous material from woollen mills. Others require very careful treatment because of their dangerous character, e.g. those from chemical works.

Finally in connection with water there is the question of using it as a solvent. Not only are beverages made from it, but also it is used widely in cooling and in making up all kinds of solutions.

Other topics concerning the home can be dealt with on similar lines to those I have indicated for water.

2. Transport

Under this heading we might deal in successive years with the bicycle,[5] the steam engine,[6] the internal combustion engine[7] and the electric motor.

These four subjects bring in a variety of scientific applications. The bicycle is an example of how we can harness our own energy through a lever system in order to propel us along. Here we can introduce such matters as the triangle of forces, pulleys, mechanical advantage, springing, lubrication and friction.

In the steam engine we can see how steam can be harnessed for our use. This introduces additional subjects, particularly the loss in energy from the supplying material such as coal to the mechanical power produced. Pistons and cylinders and the fly-wheel are brought in. The subject of gears might also be considered.

The internal combustion engine shows how we can make use of a simple chemical reaction to provide motive power. Here we have in the cylinder of the motor car engine a splendid example of expansion and contraction following the explosion of two gases (petrol and air) mixed together. The motor car introduces many scientific principles. This is largely a self-contained unit with its own cooling and

electrical systems. Both of these are worthy of detailed investigation. The springing system is a remarkable arrangement with leaved springs, shock absorbers and pneumatic tyres.

In the last year we might consider the electric motor as used in electric trains. Here we have a comparatively simple arrangement whereby electricity is generated and then transmitted along lines or wires to the electric motors in the train. This is not a self-contained unit like the internal combustion engine because of the necessity for the motor to be in constant contact with a supply of electricity.

3. Hobbies

This provides an opportunity to encourage scientific hobbies such as photography. Such a topic gives a useful link with the scientific society. In lesson time the children can learn the principles of photography such as exposure, focusing, developing, printing and enlarging and in the scientific society periods they can practise their own photography.

4. The Workshop

In this section an opportunity is afforded to consider the scientific principles at the basis of the work carried out in the wood and metal workshops. The children learn about the numerous uses of the inclined plane as a chisel, a plane and a screw. They get opportunities to examine sections of different kinds of wood in order to see how their properties are related to structure. This is also a good place to consider the properties of materials in general and metals in particular. It always seems to me that there is a wonderful diversity of metals suited for any purpose. Think for example of toughened steel, malleable lead, ductile copper, light aluminium, resistant gold and easily melting alloys of various kinds such as pewter. Electroplating can well be introduced here.

5. Health and the Human Body

In this connection anatomy should be considered only in so far as a knowledge of it is necessary to understand physiology and its relationship to health.

This part of the scheme should be considered in relation to Physical Education work. We should also be concerned with nutrition and it is here that school milk and meals can have their relationship with the education of the children. Also let us consider how education develops the individual through the senses.[8] Then there is the subject of sex education.[9] Consider these in turn.

The human body so far as physical education is concerned must be thought of in terms of the skeletal framework; the muscles; the heart; lungs, circulation and respiration; the alimentary canal and its accessory organs; elimination and excretion and the nervous system. Wherever possible experimental work should be done and use made of films,[10] film strips and X-ray transparencies from local hospitals.

Nutrition is largely the basis of good health. The school meal should be considered from the point of view of how far it contributes to the nutritional needs of the children.[11] Does it provide an adequate supply of proteins, carbohydrates, fats, vitamins and mineral salts? Does it provide the right kinds of proteins? Does it provide all the vitamins necessary and does it give a daily supply of those vitamins which cannot be stored in the human body? The human body has been found to require a large variety of salts;[12] are these supplied in the school meal?

It is the author's opinion that all schools should have their own kitchens so that not only is food eaten soon after being prepared, but also so that the Head Teacher has a large measure of control over the menus and the cooking. It is, of course, desirable that the Head Teacher should have a good knowledge of dietetics.

Then there is the question of the school milk. What are the advantages to the child in having milk in the middle of the morning? It is also important to consider what the children require in the meals they do not have in school.

In this section of the scheme it is desirable to carry out simple Biochemical Tests.[13]

The subject of the senses is often omitted in a school syllabus and yet how important they are. Our education proceeds almost entirely by way of the senses. There should

be lessons on sight,[14] hearing, feeling, tasting, and smelling. Again it is useful to carry out simple experiments.

Finally in this connection we should consider sex-education. This is much discussed and is often discussed in the wrong way. Why do children require sex-education? To say that it is to improve morality is absurd for morality is concerned with ethics, not with physical knowledge. Some actions by people which are considered immoral may be due to ignorance, but they must represent a very small proportion. The reason for teaching children about sex is simply because sex is part of them just as the circulatory system is part of them. It is true no doubt that society places a restraint on the liberty of sex impulses and this question should be considered in schools. The question of sex will often occur in biological teaching so that when it is considered with regard to human beings it will not appear unusual.

6. The Garden

All Secondary Modern Schools should have gardens. These gardens form useful outdoor sources of biological teaching. When the children become interested in the school garden they will at the same time become interested in their home gardens.

The school garden should be planned not only to provide a cultural and aesthetic setting for the school, but also to show children the methods of cultivating vegetables, fruit and flowers. There should be experimental plots where scientific experiments such as variety trials, effects of manurial treatments, effects of pest controls and other work can be carried out. Any failures in the school garden should be investigated from a scientific point of view. Why did this Worcester Pearmain not bear fruit last year? Why have the tomatoes in the greenhouse cracked? Why has blackfly on the broad beans been such a nuisance this year?

All the botanical material can be obtained in the school garden. It also forms a good habitat for the study of insects. More attention should be given to insects in school. They are a form of animal life which is easily obtained, and insects of different Orders can be readily obtained from the garden.

They represent the highest class of the invertebrates. They can be easily collected and stored. All kinds of problems can be considered in relation to insects such as their various kinds of locomotion, respiration, feeding, coloration, their senses and their effects on mankind.

7. The Farm

The school rural science course should be concerned not only with livestock on the school premises and in the school garden, but also with some local farm which has some good farming methods. I should like to see model farms set up to serve groups of secondary schools. They would provide places for the study of livestock and agriculture. In addition they would supply the school canteens with much of their produce, such as meat, eggs, poultry, milk and vegetables.

In all this there is much science to be learnt. There is the mechanics of farm machinery from the simple spade to the elaborate harvester. The preparation of clean milk[15] is another subject worthy of scientific study. The farm animals, the cow, the horse, the dog, the pig and the sheep, provide excellent material for simple comparative anatomy.[16] The scientific principles of the rotation of crops can be considered. Insects come into the scheme again by way of pests of farm animals and crops and also in a positive way in connection with bees and honey. Diseases of plants and animals can also be considered.

It would be good to see some forestry in schools. Why not let school gardens have a section for a small collection of forest trees? Children can also see forestry on the large scale and learn something of forestry methods. In the school plantation they can study the characteristics of the different species of trees.

8. The Countryside

The countryside may be considered in the school syllabus each year. The seasonal aspect of the countryside can be dealt with in the primary school. The succession of the seasons Spring, Summer, Autumn and Winter with all that this implies gives children an impression of the rhythm of

nature which is particularly important at the junior school stage. In the secondary school, the study of the countryside can well lead to simple ecology in the final year. The idea behind this is to show that not only have we a rhythmical development of nature, but we have also a pattern. The countryside is the complement of the study of the farm and the garden. It represents nature untouched so far as possible by man. We may not be able to visit a St Kilda island or even a moor or the sea-shore, but we should try to show the children something of nature unaffected by man. This is difficult in a town with only parks providing anything even remotely resembling the countryside. However, it should be possible to arrange an annual school camp in a natural spot largely unspoilt and undeveloped by man. Such a camp will provide data for many months afterwards, particularly if the children can bring back specimens.

B. Science as Part of a Vocational Training

Children who are likely to need science in the vocation they engage in, will be required to take an additional science course to give them special technique and knowledge to help them to adapt themselves to their special vocations. So often in the past, the change from school to work has been abrupt. This abruptness has been largely due to ignorance of the true nature of education. If we educate the whole man, as indeed we should, we should as part of our task educate so that the change from school to work is not abrupt.

There has been a tendency to despise vocational training in the past in spite of what the great Philosopher and Educationalist A. N. Whitehead has said,[17] "The antithesis between a technical and a liberal education is fallacious. There can be no adequate technical education which is not liberal, and no liberal education which is not technical: that is, no education which does not impart both technique and intellectual vision."

Our work is surely a vital part of our living. The more nearly the work becomes part of our higher self the finer it becomes. We must not despise vocational training, we must encourage it. Much of Grammar School education is voca-

tional training for the professions and as such it is highly successful in the main. Technical education has not been so successful, because it has been considered second best, yet technology requires just as good an intellect as any of the professions and it often requires greater skill. The Secondary Modern School still largely comes third and takes about 70 per cent of the population when the brightest children have gone to Grammar and Technical Schools. This is surely wrong. The Secondary Modern type of education is a different type from the Grammar and Technical; it is not an inferior type for inferior children. It is an education of a more practical type; an education which can be successfully carried out by children with lower mental capacities than those who can successfully carry out Grammar and Technical courses. This means two things. In the first place there is no reason why bright children who are interested in what the Secondary Modern School has to offer should not go to the Secondary Modern School rather than to the Secondary Grammar or Secondary Technical Schools. The second point is that far too many children go to Secondary Grammar and Technical Schools who would do better in Secondary Modern Schools.

Let me now relate these ideas to Science in the Secondary Modern Schools. Since I shall be dealing with this subject from other points of view in chapters 4 and 8, I will be comparatively brief in this chapter.

1. Chemistry

The boys and girls who are likely to work in laboratories should receive consideration. These will later take National and Higher National Certificates in Chemistry at Technical Colleges if facilities are available and if they are keen.[18]

The chemistry which they do in school during the last two years should be based on the common elements and their more important compounds. Some chemical theory, particularly that related to the periodic table and a little organic chemistry can be introduced. In many ways organic chemistry is more easily assimilated than much of the inorganic chemistry which is taught and it is often more valuable.

2. Engineering

The engineering varies with the district. It can be divided into several kinds such as civil, mechanical, electrical, mining, textile, small scale and large scale. The kind which is catered for may be based on local engineering or it may be on general lines. There is something to be said for both.

In this subject we would expect children to have facilities for continued study in Technical Colleges leading to definite qualifications.

The science in school would be largely based on mechanics, heat and electricity with the chemistry of the metals.

3. Building

Children who are interested in building should have facilities when they leave school to continue the work in evening institutions and Technical Colleges with building courses, including such subjects as carpentry, concrete technology and plumbing.

The science which they do in school should be based on statics and hydrostatics, the chemistry of building materials and the study of the chemical reactions involved in such processes as cement manufacture; the drying of plaster of paris and paint and the corrosion of metals.

4. Horticulture and Agriculture

There are far more opportunities for children to take agricultural courses at Agricultural Colleges and Farm Institutes than there used to be. There is probably still need for expansion of these institutions. The Royal Horticultural Society offers encouragement for the continued study of horticulture.

In school, the science should be a rural type of science with complementary courses in the garden and on the farm on the one side, and laboratory work on the other. The pure science concerned will be based on the chemistry of fertilisers, plant processes and animal processes; the biology of plants and animals and a special study of soils, pests and diseases.

5. Navigation

In a school near to a port it might be useful to give some training in navigation. Such a course might well

be based on meteorology, mechanics, hydrostatics and electricity.

6. Textiles

In a district where textiles form a staple industry it would be useful for children who are likely to go in for this type of work to undertake a science course of a special type.

It should include the simple study of fibres[18] with the study of the physics and chemistry of fibres. Mechanics would also be useful since those who work in textile factories have to deal with machines. An introduction to the knowledge of colour and dyeing would be helpful. The course might also include bleaching.

7. Domestic Science

A number of the girls in the school will wish to go in for domestic science either for the purpose of earning a living or for the important vocation of housewife.

Domestic science is largely based on science. Cooking, cleaning and other aspects of the subject are really applied sciences. Such a course should include a study of nutrition, cleaning agents and the properties of materials particularly metals. A knowledge of human physiology is also useful in such a course.

8. Nursing

Girls who wish to go in for nursing will require to know a good deal of science. Whilst there is much more in nursing than science, it is probably true that it would be a good thing if nurses knew more science.

In particular a knowledge of human anatomy and physiology is indicated. Added to this there should be some biochemistry (including nutrition).

I have briefly tried to indicate special science courses which might be included in Secondary Modern Schools for children aged from 13 to 15. The types of courses to be arranged will depend on the locality and the general facilities of the school. The criticism that is likely to be made of

this suggestion is that there is neither the accommodation nor the staffing to carry it out. If we can agree that it is desirable and enough determination is shown, the accommodation and the staffing will be provided in time.

In the meantime, something should be done along these lines. It will usually have to be a compromise but of this I am certain, that alternative courses should be offered to children at 13 according to their abilities and aptitudes. If not, then it must be denied that the important part of the Education Act 1944 which says children should be educated according to age, aptitude and ability is being implemented.

Since this book is concerned with science I have not indicated the other subjects which would come into the various courses. For example a course in Navigation would include Geography and Mathematics; a course in Engineering would include Mathematics, Wood and Metalwork and a course in Nursiog would include English for precise description.

In this chapter, I have tried to indicate the lines on which the content of a Science course in a Secondary Modern School should be based. The reader will probably not agree with all of it. He will, for instance, say perhaps that there are certain omissions. In that case he might feel that in his particular school there should be certain additions. On the other hand, he might desire to leave other topics out. That is as it should be.

It is neither possible nor desirable to lay down a science syllabus for every Secondary Modern School. In chapter 4, I shall indicate how a syllabus should be planned in relation to environment and the capacity and needs of the children.

C. How Far Can We Introduce Modern Scientific Developments into the Curriculum?

Whilst it is desirable to keep a science course up-to-date, it must be realised that there are often one or more difficulties in the way of introducing modern scientific developments.

The first relates to the complexity of many modern scientific developments such as the electron microscope, television, new drugs, plastics and viruses.

The second, which is usually found present with the first, is the difficulty of carrying out experiments to illustrate such modern subjects, which will be intelligible to even the oldest A form in a Secondary Modern School.

A useful way of introducing such topics as cosmic-rays, X-rays, ultra-violet rays, infra-red rays, wireless waves and other electro-magnetic waves would be first of all to consider the subject of these waves in general. A big chart[20] on which these were indicated might be a useful focal point. From a consideration of the properties of the various electro-magnetic waves it should be possible to deal with such subjects as the simple wireless set and radar.

The study of wireless might begin with a simple crystal receiver with fixed coil and variable condenser. Then we could lead on to a one valve set. More complicated sets could be considered with different stages, giving reasons for the uses of varying types of valves, and of such devices as chokes, transformers, fixed resistances and fixed condensers. Finally it may be possible to consider the various properties of a cathode ray tube and how it is employed in a television set.

Atomic fission might arise from a general study of atoms and molecules in the last year. Although the actual method used for separating the two isotopes of uranium to produce U235 (which was the active element in the atomic bomb), is not easy to make simple, it is possible to explain fairly easily how atomic-fission takes place. By way of illustration it is useful to show the film on Atomic Physics[21] and possibly some uranium salts. The fluorescent nature of these salts is most characteristic.

Jet propulsion, in which power is developed without pistons is fairly simple to illustrate. If a balloon is allowed to develope a small leak it moves forward in the opposite direction to the leak. This principle is illustrated in fig. 1. In the jet propulsion engine, gas escapes from the rear forming a jet and thereby develops reaction power. With the propeller attached to the shaft, the jet engine has thereby two kinds of thrust. Jet propulsion can be considered a late development of the ancient engine known as Hero's engine in which escaping steam caused the rotation of a small propeller.

Since synthetic plastics of varied types form quite a large proportion of the articles in common usage, it should be possible to include some information about them. Mention may be made of their physical properties and with intelligent children a little of the chemistry may be attempted. Plastics in general are classified as thermoplastic and thermosetting. The thermoplastic class includes materials, natural and synthetic, whose shape can be altered by heat and pressure. On

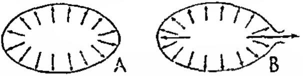

Fig. 1. Gas pressure inside a closed shell (A) pushes equally against all sides. The shell now stands still, but when an opening at one end (B) lets the gas out with no force to cancel it, the pressure at the other end makes a thrust from the shell.

the other hand thermosetting plastics are all synthetic, and in their finished forms remain rigid and unchangeable. The chemistry of plastics must include some account of polymerisation as this is the essence of the molecules forming plastics. A number of experiments can be carried out to illustrate plastics.

Some modern drugs and their uses may be considered. There was a striking experiment which came to notice quite by accident. Some of the author's students had been preparing cultures of bacteria from raw water. These cultures were developing quite rapidly on agar agar nutrient medium in a petri dish when a mould began to make an appearance. This mould grew and soon dominated the flora of the dish. It was possible to witness its gradual depredations of the bacterial flora. This reminded us of the famous experiment which Fleming himself came across by accident and which led to his isolation of penicillin.

Whilst much of modern science is fascinating to the adult, we must be careful how much we introduce into the Science syllabus and how complex we make its subject matter.

Summary

A. The Background Science:

1. The Home.
2. Transport.
3. Hobbies.
4. The Workshop.
5. Health and the Human Body.
6. The Garden.
7. The Farm.
8. The Countryside.

B. Science as part of a vocational training, e.g.:

1. Chemistry.
2. Engineering.
3. Building.
4. Horticulture and Agriculture.
5. Navigation.
6. Textiles.
7. Domestic Science.
8. Nursing.

C. How far can we introduce modern scientific developments into the curriculum?

References (Chapter Two)

(For an explanation of Film abbreviations see Chapter 12)

[1] W. H. Pearsall, A. C. Gardiner and F. Greenshields, *Freshwater Biology and Water Supply in Britain* (Freshwater Biological Association of the British Empire), 1946.

Biology of Water Supply (British Museum), 1948.

B. A. Southgate, *The Problem of Pollution of Water*, (Science Progress, XXXV, *139*, 432-447).

[2] Film: "The Filter". 35 and 16 sd. G.B. Loan charge.

[3] Film: "Taken for granted". 16 sd. C.F.L. U.K. 1136. Free.

T. B. Reynoldson, "An ecological study of the enchytraeid worm population of sewage bacteria beds: synthesis of field and laboratory data," *Journal of Animal Ecology*, Vol. 17, No. 1, 27-38.

[4] Film: "Elimination". 16 sd. G.B. Loan charge.

[5] Film: "How a bicycle is made". 16 sd. C.F.L. Free.

[6] Film: "The Steam Engine". 16 sd. C.F.L. Free.

[7] Film: "First Principles of the Petrol Engine". 35 and 16 sd. P.F.B. Free.

"Internal Combustion Engine—Four Stroke Cycle." 35 and 16 sd. P.F.B. Free.

[8] J. A. Dell, *The Gateways of Knowledge* (Cambridge University Press), 1912.

Film: "Vision". 16 sd. G.B. Loan charge.

[9] E. F. Griffith, *The Road to Maturity* (Methuen).

Film: "Sex in Life". 16 sd. Parts 1 and 2. G.C.H.E. Loan charge.

[10] Films on the Human Body such as:

"Your children's eyes." C.F.L. 16 sd. Free.

"Your children's teeth." C.F.L. 16 sd. Free.

"Your children's ears." C.F.L. 16 sd. Free.

"The Circulation." G.B. 16 sd. (colour). Loan charge.

"Blood." G.B. 16 sd. Loan charge.

"Breathing." G.B. 16 sd. Loan charge.

[11] Nutritional needs of children. See J. Drummond, *Nutritional Requirements of Man in the Light of Wartime Experience* (Royal Institute of Chemistry), 1948.

[12] Salts required in the human body. See Mitchell, *A Textbook of Biochemistry* (McGraw Hill).

[13] Biochemical Tests. See Bibby, *Simple Experiments in Biology* (Heinemann).

[14] Pirenne, *Vision and the Eye* (Pilot Press).

[15] Ministry of Education Visual Unit-Silent Film (16 mm.) on Milk.

[16] Sanderson, *Inside Living Animals* (Pilot Press).

Sanderson, *Inside Farm Animals* (Pilot Press).

[17] A. N. Whitehead, *The Aims of Education and other Essays* (Williams and Norgate Ltd.).

[18] *The Profession of Chemistry* (Royal Institute of Chemistry).

[19] J. G. Cook, "Man Made Fibres", *School Science Review*, Vol. XXVIII, *106*, 297-303.

"Symposium on Fibres", *Transactions of the Faraday Society*, 1946, Supplement B.

[20] *Chart of Electromagnetic Radiations* (Science Museum).

[21] A Film produced by G.B. 16 mm. sound. Loan charge.

CHAPTER THREE

METHOD

A. Reading

The most general way of obtaining knowledge is by reading. Although Science is a practical subject, much of it is learnt by reading. Even research scientists must, in the course of their work, read about the efforts of contemporary and past scientists. To them there is usually little point in carrying out experiments which have been satisfactorily carried out by others. From this arise two valuable guides in considering what children should read in science.

Some of the reading should be linked with the practical work which the children are called upon to do. The science teacher might well produce written accounts of experiments with conclusions and results which the children can read and study. Some of these accounts should have faults in method, in calculation and in argument. The children can read the accounts critically and try to correct them by carrying out the experiments for themselves to test the veracity of the article in question. To cultivate critical reading is an important aim of education.

The other point which arises from the first paragraph is this: the recorded practical work done by great scientists often provides good reading matter. It is desirable in school to encourage such reading.

The project method[1] lends itself particularly well to this treatment. A group of children can work together as a team to investigate a problem scientifically. The group should appoint a leader and he, with the help of the teacher, can organise the work. This group may be doing some ecological work in connection with an oak wood. Two children might survey the wood topographically. Another two might divide it into 10-yard squares and plot the trees, with names, on a map. A further two children can plot the shrubs. Other children can map the ground flora. In this way the work proceeds and data is accumulated. With the help of the

teacher, the data is summarised and conclusions drawn where appropriate. It is obvious that more work is done this way than by children working individually in isolated units. What is more valuable is that the work has more purpose.

The children will be encouraged to read about the work they are carrying out. If the work is made interesting, they will want to read not only text-books but books written on specific subjects by experts. Text-books are all right for their purpose, that of providing general information in a compact form. Because of this, parts of them are usually dull. A text-book writer can seldom be an expert on all the subjects covered in the book particularly if it is, for example, "A Text-Book of Physics". It is good if the school can provide books on special subjects, understandable by children, but written by an authority.

Time given to reading in school should be very carefully considered especially in a subject like science, which is essentially practical. Science periods are so few that it seems a pity to devote portions of them to reading by the children when there is so much practical work to be done by the pupils and so many useful demonstrations which can be carried out by the teacher. I would rather that children read about science in definite library periods and during leisure at home.

Schools usually have a limited amount of money to spend on books. When this is the case, it is far better to get a variety of science books than to get sets of 30 or 40 text-books of the same sort. Every secondary school should have a good library from which children can borrow books to read at home. The library[1] should have a good selection of science books (including some text-books).

B. Talks and Demonstrations by the Teacher

It is probably true to say that teachers in general talk too much. Whilst there are occasions when teachers can usefully talk for about twenty minutes to children while they listen, this is often overdone. The best lessons are those where there is a kind of ebb and flow between teacher and children, where

the teacher and taught are really part of an educative process. It is in an atmosphere of this kind that children develop in the best way.

When the science teacher gives a lesson he should go to great lengths to make the subject matter clear. Accuracy and precision are essential to science so that not only is it desirable to make a lesson clear so that the children shall understand, but it is also essential to the nature of science to be lucid in explanation.

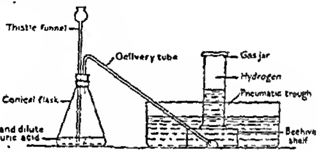

Fig. 2. Apparatus for the Laboratory Preparation of Hydrogen.

A science lesson is illustrated in a number of ways. First let us consider the use of the blackboard. This is the teacher's most useful visual aid. The teacher can make drawings quickly and put in just what he wishes the children to see. That is the advantage which the blackboard has over a diagram or drawing bought from a supplier. The teacher can build up his diagrams on the blackboard. This is a useful teaching method and as far as I know there is no better aid in using the development method.

Sometimes it may be necessary to prepare the blackboard diagrams before the lesson begins because of the time taken up in its preparation. In this case I would certainly leave the labelling till the actual lesson and possibly some of the fine details. It is good to let a diagram 'grow' whilst the class is present.

Good lettering is essential for labelling drawings. Practice in lettering will enable teachers to make far better use of the

blackboard. When labelling a diagram let all the letters be horizontal and draw lines to the various items on the diagram (see illustration fig. 2).

Although in adult work I would suggest that colour should be used sparingly, in the matter of teaching children there is a good deal to recommend the use of coloured chalk. Diagrams and lettering appeal to children far more if they are in colour.

When a drawing or diagram is required for a number of lessons, that is the time to produce a permanent effort on card. It should still be simple. It is a waste of time to make elaborate charts because complexity often spoils their purport. Coloured Indian inks are useful for the line work and poster colours for the flat washes.

Science demonstrations often include the use of experiment. In considering the question of experiment there are several matters to have in mind.

In the first place an experiment may be carried out by the teacher in order to show the children how to carry it out themselves. It is obvious that, in such a case, the teacher should employ an identical set of apparatus to that which they will subsequently use. An important point is that the children should all be able to see clearly what is taking place. This is often difficult with this type of demonstration, because it is not lecture room apparatus which is specially meant for an audience. In the case of demonstrating an experiment which the children are later to carry out it may be desirable to let groups of children come out to the demonstration bench in turn to see the stages in the development of the experiment. If this has to be done, then the children who are not watching the demonstration should be engaged in some other useful work appertaining to the subject.

For large scale demonstration the teacher must spend a good deal of time thinking and devising experiments to make principles clear and to show children the various types of experiments necessary to illustrate the numerous subjects of the science course. There are many sources[3] from which the teacher can get ideas for experiments. If he is a good teacher, he will work out some for himself. The science teacher should

be something of a conjurer, but unlike the conjurer he must explain his tricks.

When carrying out demonstration experiments, the teacher should make sure that everything is in order before the lesson begins. So far as he can, he ought to be certain that the experiments will prove his points. The bench can be well illuminated either by daylight or by electric floodlights. The background to the demonstration is important. It may be necessary to have a white background or a black background to show up the apparatus to the best advantage.

The general order and tidiness of the bench is important. Nothing looks worse than a demonstration bench littered with books and bespattered with miniature pools of water. Only have on the bench the materials and apparatus relevant to the lesson in hand. The teacher should avoid having even his notebook on the bench.

Demonstrations may also include the use of films, film-strips, lantern slides or the micro-projector. This is dealt with in Chapter 12.

C. Experimental Work by the Children

1. In the Laboratory

Experimental work by the children should be carried out both in the laboratory and outside the school.

Facilities for laboratory work vary according to what the particular school can offer in the way of staff, laboratory accommodation and equipment.

If the staffing is generous, it may be possible to arrange to have not more than 20 children for practical science. The class should be no bigger than this so that the teacher can not only supervise the children satisfactorily, but also to enable him to get round to individual children to guide them in their work. When the usual size of classes in the school is about 40, practical science is most usefully conducted in half classes.

Laboratory accommodation is another problem. This accommodation is not only concerned with the size of the room, but also the furniture of the room. When experiments

are to be carried out demanding gas or electricity points or sinks, the facilities are limited by these matters.

Equipment is another factor which complicates the matter of practical work, because some items of equipment such as bell-jars, pneumatic troughs, potentiometers and microtomes are not usually there in sufficient numbers for all the children in a class to use them at the same time.

The author has solved the problem in this way. By arranging a large number of experiments so that individuals can carry out different experiments, it is possible to use apparatus economically. If the experiments are numbered and if the children are given experiments to do which are not beyond their capacity at the time, the system can be made to work efficiently. When there is ample cupboard room, the sets of apparatus for the different experiments can be placed in numbered cupboards together with sets of typed instructions. The list of experiments can indicate in which cupboard the equipment is to be found. If children are carrying out different experiments they rely more on their own abilities because they cannot copy others. This is a particularly good point in practical work. In this system, the children can in the course of time cover all experiments necessary for the scheme of work.

In arranging practical work, it is desirable not to make experiments elaborate. If the experiment elucidates the principle it is desired that the children should understand, that is sufficient, if that is the purpose for which the work is intended.

This leads on to the subject of the types of experiments. In general it can be said that experiments are of five kinds.

1. An experiment to illustrate a principle.
2. An experiment to find a numerical result.
3. An experiment to produce something.
4. An experiment copying an experiment carried out by a famous scientist.
5. Original work.

In the case of the experiment to find a numerical result it is desirable to allow the children to use apparatus suffi-

ciently good to enable them to get a reasonably accurate answer. This is important if they are to realise the importance of accuracy in scientific work. In experiments of this kind, the teacher should point out the source of error.

Experiments to produce things include such experiments as the preparation of chemicals, the pressing of flowers, the making of microscope slides and the making of an electric motor. In all this work, it is important to insist on a good standard of achievement. This can be facilitated by using good equipment and materials and by ensuring that the work is within the capacity of the children.

Before carrying out such work, the teacher should explain the process carefully and he should tell the children where they are likely to go wrong if they are not sufficiently careful. Where possible, the teacher should demonstrate the process so that all can see clearly.

Sometimes it is desirable for children to imitate the work of a famous scientist in one of his experiments. Quite often the apparatus may not look similar, but it may act in the same way. The value of such experiments lies in the feeling the children are likely to have for the scientist who has carried out the experiment as original work. A visit to the Science Museum or Royal Institution, London, would act as a stimulus to this kind of experiment.

2. In the Field

It is desirable that children should do a certain amount of original work. Much of this will be related to field work because the chance of children finding anything new in Physics or Chemistry is remote. There are, however, opportunities for finding out new knowledge in the realms of ecology. The thrill of discovery gives zest to the pursuit of knowledge. Children, like sensible adults, enjoy exploration. Fields of exploration differ, but the zest of discovery in all cases depends on finding something which was unknown to man before. If we encourage this in children, there is a good chance that they will grow into adults who are desirous of extending knowledge.

This type of work encourages good reading and the pursuit

of references. To find out if knowledge is really new, you have to consult works of reference to determine if anyone has made the discovery before. Books have also to be read in order to improve methods of discovery. Practical techniques have to be perfected. You may have guides, but eventually you have to think for yourself because no one has trodden that path before. It is all most stimulating.

Children in the past have spent far too much time in school buildings. Happily we are beginning to realise that education is concerned with the full life, not with the rarefied atmosphere of the classroom or library alone. Consequently we find that teachers now take classes of children out of school during school hours for other purposes than games and visits to the baths. At present the efforts are rather timorous, because teachers tend to be conservative in their methods and parents are apt to think that children should be confined to the school buildings during school hours.

Outdoor practical work in science is concerned with nature and with man's adaptation of nature. In the former case the children should carry out the ecology of areas as nearly wild as can be found within a reasonable distance of the school. This is not easy in a city for obvious reasons. However in these cases there should be opportunities through school journeys and school camps. The best regions for ecology of wild places are woods, moors, some commons, bogs, lakes, ponds and the seashore. It should be part of the aim of the teacher of science to include as many of these types as possible in the science course.

Then we have such subjects of study as farms, canals, railway embankments, tips, hedgerows, grass verges, the ecology of ruins (old and new) and the flora and fauna of reservoirs.

All the above are concerned with ecology and require a knowledge of ecological methods.

These methods can be studied in the books given at the end of the chapter.[4] They should include soil testing, making transects of various kinds, water sampling, measurement of humidity and preparing an ecological herbarium.

The children should also learn how to collect insects[5]

using the beating tray, the "sucker", the sweep-net[6] and the butterfly net.[7] Methods in setting out insects in boxes[8] should also be given. Help in identification will be necessary.

Identification is not easy. In the case of insects it is best to learn how to recognise the various orders first. After that children might learn to recognise families and the genera. It is more scientific to proceed in this way rather than to try to spot an insect in a book by the mechanical method of turning over the pages until you find its likeness on the printed page.

Plants can either be pressed or preserved in special ways[9] according to requirements. It is necessary in making a herbarium to get complete plants with roots and to arrange the plant in as natural a way as possible on the sheet. A word of caution should be given in the case of rare plants. These should not be taken up by the roots. A flower and leaf can be taken with safety.

When any plant or animal is brought back to the laboratory, full details should be brought as well, including habitat, date, name of collector and geographical area.

The Ecology should also include bird study[10] and insect migration studies.[11] Direct observation of birds and insects often produces useful information. The study of birds should encourage the love of birds.

Children with cameras may be encouraged to take some ecological photographs. Although these are considered to be difficult, I think some efforts should be made. If there are any short focus cameras then close-ups of plants or even butterflies might be attempted.

The work in the field should be correlated with that in the laboratory. I will give some examples. Samples of soil can be brought in and tested in various ways. They can be weighed, then allowed to dry in the air, then heated and finally calcined. The differences between these give values for the following kinds of soil water respectively: (*a*) Available water, (*b*) Hygroscopic water, (*c*) Capillary water.[12] Soil can be extracted with Morgan's reagent[13] and tested for various elements. An aqueous solution of soil can be tested

for pH.[14] An extracting mechanism which I have perfected is illustrated in fig. 3.

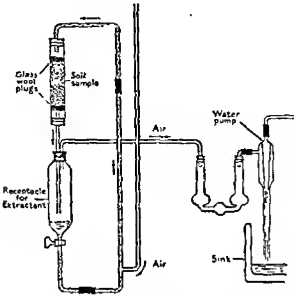

Fig. 3. Apparatus for treating soil with Morgan's Reagent.

Samples of soil can be spread out on damp blotting paper to see if there is any seed germination. The plants that grow can be transferred to seed boxes and later identified.

The animal life can be extracted from the soil either by placing the soil in a fish kettle with a perforated bottom over a bucket of boiling water when the steam will drive the animal life to the surface or by the use of the Berlese-Tullgren funnel.[15] In this apparatus (see fig. 4) the light and heat from the lamp encourage the small life, mostly Collembola, to fall into the alcohol.

The soil can also be tested for general composition including rough proportions of clay, sand and humus.[16]

Some grasshoppers lay their eggs in bare soil and some in grassland. Since the eggs hatch out in May, it is a useful experiment to bring in samples of soil in March and place them in vivaria. Then when the grasshoppers hatch out it should be possible to divide them into the two groups of

those that lay eggs in bare soil and those that lay eggs in grassland. It is necessary to observe where grasshoppers spent most of their time in the previous year in order to tell where to get the soil from. Another experiment with grasshoppers would be to see if they would change colour with their surroundings. *Chorthippus bicolor* exists in such colours as red, brown, green, and yellow. These could be put respectively in vivaria where surroundings were red, brown, green and yellow to see if a group of grasshoppers of different colours would all change to the colour of the particular vivarium. Probably the simplest way to get different colour effects would be to use different coloured glasses. The only trouble here might be that the health of the grasshoppers would be affected. Alternatively the interior of the vivarium could be painted a particular colour, but then we should always have to have grass which was predominantly green.

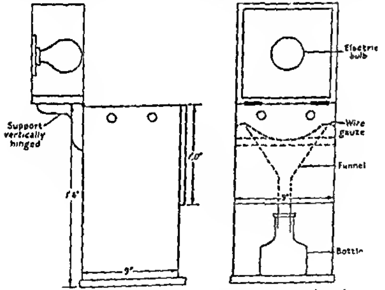

Fig. 4.

I have indicated two kinds of correlation between field and laboratory. There are many other examples which should occur to the active teacher.

Part of the science work should involve visits to such places as water works, power stations,[17] gas works,[18] textile factories, foundries[19] and so on. Before children go to these places they should have preliminary lessons and if possible they should see a plan of the place they are going to visit. It is desirable that the teacher should visit the place before the children so that he will know exactly what they are likely to see.

When the visit is made, the group should be small enough for all to hear what the conductor is saying. Care should be taken to ensure that nothing on the visit is beyond the mental capacity of the children. So often the talk can become very technical and unintelligible except to the specialist. It is also important to see that the matter covered in the visit is not too extensive. Too much information at a time tends to produce mental indigestion. The visit should be followed up with appropriate lessons. Visual aids are often a help; it may be appropriate to bring samples of materials, pamphlets, and charts There are occasions when it is possible to show films or film strips about the visit.[20]

The good science teacher develops his own methods to suit his skill and ability. Some teachers can make better use of certain methods than others. There are no golden rules to successful science teaching. I have given guides, it is necessary for the science teacher to perfect techniques peculiar to himself.

3. Practical Work with a Class of 30 to 40 Children

Sometimes it is not possible for a teacher to have less than 30 children for science lessons. Under such conditions, a teacher may feel that it is impossible to allow the children to carry out practical work. However, to take such a pessimistic view is unfortunate for it is to deny the children an opportunity to do science as it should be done. Unless children carry out experiments for themselves, they will never get to know what science really is.

The conscientious science teacher will consequently devise means of overcoming the difficulty of a large class. He will do

this in a number of ways. In the first place he will work out a series of experiments requiring only simple apparatus to demonstrate the principles he wishes his pupils to assimilate. To this end he will invent techniques using such articles as jam jars, test-tubes, cardboard, metal clips, plasticine and dowel rods. This sort of thing will bring out the ingenuity of the teacher and with a good teacher it will also bring forth ideas of experiment from the children. For the pupils to make suggestions about experimental methods is of sound educational value.

Another point is that the experiments should be easily carried out, preferably in one lesson. This is not the same matter as using simple apparatus though it is sometimes related to the simplicity of the apparatus.

A third point concerns the giving out and collecting of materials and apparatus. In many Secondary Modern Schools there is no full time laboratory assistant and this being so, the teacher will perforce have to work out methods for the quick giving out and collection of the materials and apparatus which the pupils will use. This involves an intelligent use of cupboards (related not only to sizes of cupboards, but also to proximity to the pupils' positions). It is particularly necessary to have sets of glass tubes bent for special purposes fitted where necessary with corks. These latter should in turn fit the flasks and test-tubes in use. If the laboratory is small in size for the classes that occupy it, then it may be necessary to use small scale apparatus, substituting for example 4 inch by $1\frac{1}{2}$ inch specimen tubes for gas jars, and diminutive deflagrating spoons for the standard size articles. It is important to realise that efficiency of apparatus is entirely unrelated to its size. In the use of chemicals it is both economical and good scientific training to use small quantities where possible.

With large classes, it is necessary for the children to work in groups either because there is not enough apparatus to go round or because the room is not big enough for each child to have a set of apparatus. In this there is a danger that one enthusiastic member of each group will do the work whereas the other members will do very little. This can be obviated

by having equal groups say of three children and numbering them 1, 2 and 3. If each group will carry out one experiment during the lesson, then the teacher can specify that No. 1 in each group carries out stage 1, No. 2, stage 2 and No. 3, stage 3. This ensures that all the children take their full share in the work.

If on the other hand there are three different experiments to be done during the period, then No. 1 can do the first, No. 2, the second and No. 3, the third.

In conclusion, the children should all be observed by the teacher from his desk or bench. This is most important not only for giving instruction but also to avoid accidents which can easily occur, particularly if some bench positions cannot be observed by the teacher from his bench. The author is not suggesting that the teacher should remain in one position during a practical lesson. The teacher's power of control over the class should be such that the children go on working satisfactorily when he is walking round and giving individual help where it is needed.

Summary

A. Reading.

B. Talks and Demonstrations by the teacher.

C. Experimental work by the children.
1. In the laboratory.
2. In the "field" (considered in its widest sense as the world outside of school).
3. Practical work with a class of 30 to 40 children.

References (Chapter Three)

[1] See appendices 1, 2, 3, 4.

[2] See chapter 11.

[3] *Science Masters' Book:* Series I, Part I—*Physics* and Part II—*Chemistry & Biology*; Series II, Part I—*Physics* and Part II—*Chemistry & Biology*; Series III, Part I—*Physics*, Part II—*Chemistry*, Part III—*Biology* and Part IV—*Experiments for Modern Schools* (John Murray).

G. Fowles, *Lecture Experiments in Chemistry* (Bell), 1947.

Teaching of Science in Secondary Schools, pages 279, 280 (John Murray).

[4] *Books on Ecological Methods:*

W. Leach, *Plant Ecology* (Methuen).

H. Drabble, *Plant Ecology* (Arnold).

R. Bracher, *Ecology in Town and Classroom* (Arrowsmith).

R. Bracher, *Field Studies in Ecology* (Arrowsmith).

R. C. McLean and W. R. Ivimey Cook, *Practical Field Ecology* (Allen and Unwin).

A. G. Tansley, *Introduction to Plant Ecology* (Allen and Unwin).

C. Elton, *Animal Ecology* (Methuen).

C. Elton, *Animal Ecology* (Sidgwick and Jackson).

[5] British Museum: "Notes for Collectors-Insects." 1s. 6d.

[6] L. G. F. Waddington, *Making a sweepnet* (Amateur Entomological Society).

[7] *Journal of the Amateur Entomological Society*, Vol. 5; No. 38. 4s. 6d.

[8] B. A. Cooper, *Setting Lepidoptera* (Amateur Entomological Society).

[9] See *Biological Techniques* (chapter 6, section A5); also H. S. Thompson, *How to collect and dry flowering plants and ferns* (Routledge). 7d.

[10] Bird Study: see Bulletins of the British Trust for Ornithology, 91, Banbury Road, Oxford.

[11] Migration Studies of Insects: see C. B. Williams, *Butterfly Migration* (Daily Mail School-Aid Publication).

[12] Leach, *Plant Ecology*, pages 69-71.

[13] M. F. Morgan, 1941, "Chemical soil diagnosis by the Universal soil testing system", *Connecticut Agr. Exp. Stn. Bull.* 450; also Symposium in *Soil Science*, Vol. 59, No. 1, 1945.

[14] See Leach, *Plant Ecology*, pages 69-71.

[15] N. Haarløv, "A New Modification of the Tullgren Apparatus", *Journal of Animal Ecology*, Vol. 16, No. 2.

[16] See Leach, *Plant Ecology*, pages 69-71.

[17] Films: "Planned Electrification". 16 sd. Metro-Vick. Free hire.

"Power for the Highlands." 16 sd. C.F.L. U.K. 432. Loan charge.

[18] Film: "The Manufacture of Gas." 16 sd. B.C.G.A. Free hire.

[19] Silent film: "Wilson's Forge". Ministry of Education Visual Unit.

[20] *Examples:* (a) *Gas Works.*

Products of the Gas Industry. These could be obtained at one time from the British Gas Association.

Films on Gas Production; pamphlets, charts, and booklets from the British Gas Council, 1 Grosvenor Place, London, S.W.1.

(b) *The Nickel Industry.*

Films, specimens, film strips and diagrams may be obtained from The Mond Nickel Co. Ltd, Thames House, Millbank, London, S.W.1.

(c) *Leather Industry:* special matter relating to the depredations of the Warble Fly.

Specimens and charts may be obtained from The Hide and Allied Trades Improvement Society, 75, Burdon Lane, Cheam, Surrey.

SYLLABUS MAKING

A. Background Science

Various bodies have from time to time suggested science syllabuses for Secondary Modern Schools. Whilst it is useful to have a basic plan, it is foolish to set down a syllabus for a typical Secondary Modern School. This is foolish for a number of reasons. In the first place there is happily no such thing as a typical Secondary Modern School. Secondly the scheme should primarily grow out of the interests and environment of the children in a particular school. Thirdly it must to some extent depend on the equipment, teaching staff, and size of classes in that particular school.

Let us consider these in turn. Since Secondary Modern School courses are not punctuated by public examinations such as the General Certificate in Education they have no excuse for conforming to type. This should be a good thing, but on the other hand it is sometimes a bad thing. It is good in that the school can make a scheme suitable for that particular school. It may be bad in the hands of a staff which lacks enterprise. A good staff makes the best of circumstances, but a poor staff takes the line of least resistance. For the latter, some discipline such as an external examination might be good.

The scheme should arise out of the interests and environment of the children. As I indicated in chapter 2, the scheme can be based on The Home, Transport, Hobbies, the Workshop, Health and the Human Body, the Garden, the Farm and the Countryside. Around these topics can be orientated the interests and environmental studies related to a particular school. The school in a Cornish village near to a rocky coast would have different iuteresis from a school in the centre of a Textile manufacturing town in the West Riding. A school in the Potteries would have a different syllabus from a school in Snowdonia. Again, a school near Lake Windermere would have a different syllabus from a school on the Lincolnshire plain.

Films on Gas Production; pamphlets, charts, and booklets from the British Gas Council, 1 Grosvenor Place, London, S.W.1.

(b) *The Nickel Industry.*

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Children are interested in colour which leads quite naturally to vision, camouflage and man's use of colour. Vision involves not only the consideration of the eye, but also the construction of lenses and the nervous system. Camouflage is of a number of types. There are examples of harmonising colours, contrasting colours, offensive colours and other devices. It is rather interesting to show how nature's methods of camouflage have been used in warfare. Man has used colour very widely both in a utility sense and for decoration. The subject of transmitted and reflected light should be introduced here. Such items of scenery as the seashore, sand-dunes, rivers, ponds, pine woods, oak woods, bogs, heaths and moors can with advantage be utilised in the scheme. These provide good fields of exploration for ecology and for the study of plants and animals.

Local industries suggest avenues along which science can be pursued. Mining, railway wagon works, iron foundries, glass-making and many more industries offer great scope for science.

Railways, tramways, buses, cars and other means of transport provide further examples suitable for consideration in a science course.

Then we have the sky with its clouds. A study of the sky may go beyond the confines of the earth's atmosphere to the moon, the planets, the sun, the stars and the nebulae.

The house provides a great deal of scope for lines of development in the science scheme. Such matters as the structure of the house, strength of materials, materials for decoration, food, cleaning, fuel, supply services, windows, ventilation and care of materials suggest themselves.

The school garden should provide specimens for the study of plants and animals under the specialised conditions to be seen in a garden. Here are a certain number of controlled conditions such as soil, watering, absence of weeds, pruning and grafting.

Farms provide material for the study of the growth of crops, the raising of stock and the production of milk and eggs. On good farms, the children can see how the farmer controls natural laws in order to get the best results. The

Since we are in the Romantic stage so far as science is concerned in the Secondary Modern School, it should arise out of environmental interests. Science must by its nature be factual; hence it cannot rely on imagination. The science in the Secondary Modern School should consequently be based on facts which arouse the interests of children.

Children have a natural desire to collect things. This desire can be made use of by arranging for them to collect plants, insects, leaves and so on. They can collect the plants and examine them. Specimens of plants can be pressed and a school herbarium formed. Insects can be collected and sorted out into their orders. The insects can be suitably preserved and stored. Leaves can be collected and leaf prints made. Shells can be collected and examined. Much of the biology course can arise from collected material.

This matter can be pursued further. When children collect natural history specimens they should note where they got them from; the date and geographical situation are also important, and the name of the collector should be recorded. By special mapping so that positions of discoveries can be noted much useful biology can be carried out.

Boys have a particular interest in anything that moves whether it be a beetle or an aeroplane. From this natural interest in locomotion, a whole host of scientific matter arises.

With the movements of natural objects, which usually means the locomotion of animal life, the boys can compare the movements of various forms of aquatic life such as the stickleback, the caddis-worm, the plaice, the water spider, the water-boatman and the octopus. In considering terrestrial life they can compare the movements of dogs, rabbits, snakes, lizards, centipedes and birds. There is also aerial movement to consider in such as the bat, the swallow and the butterfly.

In mechanical things, boys have an interest in aeroplanes, steam locomotives, cars, bicycles and ships. All these give plenty of scope for scientific work. Such matters as mechanical efficiency, the application of levers, the uses of gears, the power supply, friction and lubrication, methods of cooling and methods of control suggest themselves.

Children are interested in colour which leads quite naturally to vision, camouflage and man's use of colour. Vision involves not only the consideration of the eye, but also the construction of lenses and the nervous system. Camouflage is of a number of types. There are examples of harmonising colours, contrasting colours, offensive colours and other devices. It is rather interesting to show how nature's methods of camouflage have been used in warfare. Man has used colour very widely both in a utility sense and for decoration. The subject of transmitted and reflected light should be introduced here. Such items of scenery as the seashore, sand-dunes, rivers, ponds, pine woods, oak woods, bogs, heaths and moors can with advantage be utilised in the scheme. These provide good fields of exploration for ecology and for the study of plants and animals.

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Farms provide material for the study of the growth of crops, the raising of stock and the production of milk and eggs. On good farms, the children can see how the farmer controls natural laws in order to get the best results. The

best results are measured not in terms of quick production of quantity, but in quality produce as a long term policy.

In the foregoing I have tried to show how the environment can provide adequate material for the science syllabus. All school environments are rich in items of scientific importance.

Experimental work which can be done in schools is to some extent limited by staffing, size of classes, accommodation and equipment. Schools vary considerably in these four factors.

Staffing and size of classes can best be taken together because to a large degree one controls the other. Staffing is not just a numerical matter, for a teacher of science should be trained in science, consequently the science teaching should be confined to those members of the staff who are competent to teach the subject. If classes are divided for practical science in order to get a maximum size of 20 it is necessary for the remainder of the class to be taken by someone. This other teacher need not be a science teacher. With classes of 40 or over, practical work by the children must by exigency be on the small scale. Any large-scale work will have to be carried out as a demonstration by the teacher. At the present time, this will have to be the method in some schools.

Accommodation is another variable factor. Some schools are well equipped with well-appointed laboratories, but others are poorly equipped. There is many a school where science is taught that not only has no laboratory, but possesses no room fitted with a water-tap, sink, gas-point or electricity. Yet the teachers have to make the best of these conditions. Many of these difficulties can be overcome by the enterprising teacher. He may use an aspirator with tap as a

being too elaborate becomes too expensive. It is foolish to swallow up the allowance by spending it on unnecessarily expensive apparatus. As I shall endeavour to show in chapter 7, a good deal of apparatus can be made which is as good and sometimes better than apparatus bought from dealers. Good teachers will invent types of apparatus to demonstrate certain principles or to carry out certain jobs.

The Concentric System has much in it to receive approbation. In this system, the topics, the Home, Transport, the Workshop, Health and the Human Body are considered each year, but in a different way. This provides an opportunity for the revision of work done in previous years and of carrying out new work. Such a system provides a framework for the science course which is of real value to the children. In treating the Countryside, in the first year some common trees, birds and flowers may be considered. Then in the second year we might consider the life histories of some common insects. In the third year ponds may be studied and in the fourth year the children could do some simple ecology. By this means the children should be able to see the interconnections of science.

Health and Human Physiology are important subjects. They are our immediate environment, the environment which is always with us. It is suggested in the first year, the skeleton be considered. Since this is the framework of the human body it is desirable to deal with it first. This can be followed by a study of Nutrition. Nutrition should include the digestive system, food values, food storage and food preservation. The digestive system can be treated quite simply. It is desirable that children should know something of food values. Even today there is widespread ignorance of food values. The children should know something of the introconvertibility of carbohydrates and fats. They can be introduced to the subject of proteins and told that whereas carbohydrates and fats are not required specifically, this flexibility does not apply to proteins. There are certain proteins which the body must have.

It is appropriate here to introduce Vitamins, and I hope the alphabetical lettering of vitamins will be subjugated.

There is nothing mysterious about the lettering of vitamins. These letters were just put in as temporary labels. Children should be told that in many cases we know the structure of vitamins and can make them artificially. They are akin to enzymes. It rather appears to me that vitamins and enzymes help to control metabolism and that is their function. This conception, which I believe to be true, is quite simple in its principle.

A knowledge of food storage is interesting. Plants store food in their leaves and stems and often in their roots, as in carrots, turnips and parsnips. Plants store their food in an insoluble form. Now just as plants take care in the storage of food so we have to take care. We store potatoes in clamps, beef in refrigerators and fruit in an atmosphere of carbon dioxide. This is a very interesting subject[1] which should receive more attention in schools than it does at present.

The preservation of food follows from food storage. In the home we preserve fruit in bottles in various ways. In factories vegetables, meat and fruit are canned. Milk is preserved and purified temporarily by pasteurisation and sterilisation. Some foods are dried, as sultanas and figs, in order to preserve them. In the science course we should aim at revealing the underlying scientific principles.

In the first year of the course we might treat the allied subjects of circulation and respiration. These can be illustrated by models,[2] apparatus[3] and films.[4] Some microscopic work like looking at the capillary circulation in the webbing of a frog's foot or in a young tadpole is helpful. This might well be compared with the flow nf protoplasm in elodea.

During the second year, circulation, respiration and nutrition can be done in more detail. Something may also be worked out in connection with elimination.[5] The four methods of elimination by the body can be enumerated and considered in turn. There is elimination from the large intestine, sweating from the skin, expiration from the lungs and finally excretion through the kidneys. All these are worth considering. In the case nf elimination nf faeces and passing of urine, it is useful to consider how these are disposed of in our modern town planning system. Can sewage disposal be

improved so that valuable nitrogen and phosphorus are not lost?

The third year may be devoted to the nervous system and the senses. These are best left to the third year because they are probably more difficult to understand than the other subjects I have enumerated. Since electricity will be considered in connection with the home in the same year, the electrical system of a house may be compared to electrical impulses in the nervous system. Many useful experiments can be devised to show various points about the nervous system.[6] There are also good experiments to illustrate the uses of the senses.[7]

The fourth and last year may be devoted to a study of the general integration of the parts of the Human Body. This is important, because the body works as a whole. Trouble in one part of the body tends to throw the whole body out of alignment.

There should also be consideration of the social aspects of human biology. Happy family relationships can be considered in contrast to the misuse of the bodily instincts in such matters as drinking, eating, sex-perversions and so on. Consideration may be given to the interactions between the environment and the individual. Social progress is usually measured in terms of improvement of the environment for as many people as possible. Such matters as better housing, the provision of open spaces, the National Health Service, and National Insurance are all designed with this in view.

This progress is offset by errors and malpractices on the part of many people. We have social evils which at the worst lead to war, pestilence and famine. These are matters which should concern all.

Sex education should be treated here. If children do not get the education whilst at school, they are not likely to get it later on. Teachers should not shirk their duty in regard to this, but the subject should come into normal school routine not as a special course.

Nature employs two sexes so far as human beings are concerned and therefore in order to continue the species, methods have been devised by Nature for attracting the

male and female towards one another for the purpose of setting up a family unit. This is a special kind of environmental influence. The method of treatment here, briefly touched upon, should be simple and direct.

There should be some lessons on the sexual development of both boys and girls. It may be necessary to have them in separate classes for these lessons, though this is doubtful. But each sex should know about their own development and that of the other sex. It is difficult to justify not giving children a fundamental knowledge of the development of their own bodies, though there are still people who believe in withholding such information.

The last subject which should be considered in this connection is sexual selection. Children can learn something of sexual selection in animals. They can hear how farmers make use of selection to improve their cattle and sheep. This can be applied to human beings as a simple study in eugenics. It is important because it has such a profound effect on human development, generation by generation. This introduces the children to heredity and the comparison of nature and nurture.

In this chapter on Syllabus Making it is impossible to consider every possible subject for the curriculum. I have just indicated lines along which it can be worked out.

Syllabuses for the C and D Streams

This appears to be the place to consider the scheme for the C and D children. May I suggest a seasonal basis for this, with necessary additions where required?

In the first year the following are suggested.[*]

Autumn Term

Fruits and Seeds

1. Take a broad bean to pieces and see what it is made of.
2. Grow a broad bean and observe what happens.
3. What does it need in order to grow?—Water; heat; air; light.
4. What does it need in order to make green leaves?

Movement

1. How do we walk?
2. How does a beetle walk?
3. How does a dog walk?
4. *How* do *we make a bicycle go?*

Sound

The Piano

How do animals keep warm?

1. Coats of fur.
2. Coats of feathers.
3. Why do snakes have scales?
4. Why do fishes have scales?
5. Why do we only have fine hairs?
6. Why do some animals go to sleep in winter?
7. How does blood make us warm?

SPRING TERM

Winter Twigs

1. What are the roots like when a twig grows in water?
2. What do roots do?

Crystals

1. How can we make some crystals of salt?
2. Other kinds of crystals such as washing soda and diamonds. How do they differ?

Light

1. The movement of the sun in the sky.
2. The light from the moon
3. What does a plane mirror do?

Heat

1. The gas stove
2. What happens when water boils?

Birds

1. The song of birds in spring time.
2. The nests of birds.

SUMMER TERM

Communities

1. The School Garden
2. The Pond.

Shapes—round

1. Experiments with a ball
2. Experiments with soap bubbles.
3. Why is the earth roughly round?
4. Why are gramophone records, wheels, plates and tubes round?

Colours

The rainbow—how is it made?

Insects

1. How to keep insects.
2. The Life History of the Cabbage White Butterfly.

Then in the second year we might try the following scheme:

AUTUMN TERM

Fruits and Seeds

1. Germination.
2. Observations on peas, beans, maize and mustard.
3. Response to light.
4. Response to gravity.

Movement

1. How does a fish swim?
2. How does a duck swim?
3. How does a frog swim?
4. How do we swim?
5. Why does a boat float?

Sound

The flute.

How do animals eat?

1. The rabbit
2. The cat.
3. The fish.
4. The chicken.
5. Ourselves.

SPRING TERM

Winter Twigs

1. Leaf scars
2. Annual rings.
3. The opening of the winter bud.
4. Why do leaves fall from some trees in the Autumn?

The Air

1. Oxygen: the gas we breathe.
2. Nitrogen: the gas which dilutes the oxygen.
3. Carbon dioxide: the basis of food production.
4. Water vapour: the water which is essential to all life.

Light

1. The magnifying glass.
2. Spectacles: why they are worn.

Heat

1. Expansion—examples.
2. Change of state—melting and freezing; vaporisation and liquefaction.

Birds

1. How do we recognise common birds?
2. How to watch birds.

SUMMER TERM

Communities

The Wood.

Shapes—cylindrical.

1. Worms.
2. The boiler of a locomotive.
3. Pipes.
4. Snakes.
5. Stems and roots.

Colours

The colours of flowers.

Insects

1. Where to find insects.
2. The life history of the click beetle.

The third year scheme might be as follows:

AUTUMN TERM

Fruits and Seeds

1. Kinds of fruits.
2. Fleshy fruits and dry fruits; why do they differ?

Movement

1. How does a pigeon fly?
2. How does a dragon-fly fly?
3. How does a bee fly?
4. How does an aeroplane fly?
5. How does a helicopter fly?

Sound

The trumpet.

What kinds of foods do animals eat and why?

1. The rabbit.
2. The cat.
3. Fishes.
4. Chickens.
5. Ourselves.

SPRING TERM

Bulbs and Corms and Spring Flowers

1. Snowdrop.
2. Crocus.
3. Daffodil.
4. Tulip.

Water

1. Hydrogen.
2. What is water made of?
3. Solution.
4. Canals—for transporting goods.
5. Animal canals.

Light

The microscope.

Heat

Production of heat—The Sun.

Mammals

The cow.

SUMMER TERM

Communities.

The Lane.

Shapes—flat.

1. Leaves.
2. Table tops.
3. Window panes.
4. Scales.
5. The hand.

Colours

The colours of insects.

Insects

1. The parts of an insect.
2. The life history of a house-fly.

Electricity

1. The household wiring system.
2. The electric iron.

The fourth and final year might contain the following items:

AUTUMN TERM

Fruits and Seeds. Dispersal of seeds.

1. Wind. 2. Birds. 3. Self dispersal. 4. Water dispersal.

Reproduction

1. Flowering plants. 2. Bees. 3. Poultry. 4. Rabbits. 5. Human beings.

Sound

1. The drum and the xylophone.
2. The ears.

Bones

1. Examination of a sheep's skull.
2. The backbone.
3. The shoulder girdle.
4. The pelvis.
5. The bones of the limbs.

SPRING TERM

Metals

1. Iron.
2. Copper.
3. Aluminium.
4. Tin.

Light

1. The eye.
2. Examination of a bullock's eye.
3. The telescope.

Heat

1. Production of heat.
2. Coal and coal gas.

Mammals

Ourselves.

1. Breathing. 2. Circulation. 3. Digestion.

SUMMER TERM

Communities

The human community and its relation to plants and animals.

Shapes—streamline

1. Birds. 2. Fishes. 3. The aeroplane. 4. The submarine
5. The ship. 6. Our own shape.

Colours

The colours of birds.

Insects

(*a*) What does an insect do and how does it do it?

1. Breathing.
2. Eating.
3. Nutrition.
4. Seeing.
5. Hearing.

(*b*) The life history of a dragon-fly.

Electricity

1. The fuse.
2. The switch.
3. The electric motor and its application to the Vacuum Cleaner.

B. Syllabuses for Specific Sciences

Arranging syllabuses for the specific sciences as outlined in chapter 2, will be somewhat easier than the foregoing for the subject matter will be largely predetermined.

Whilst the subject matter should primarily arise from the vocational needs of the course, there should be some sense of balance. The course should not be planned on narrow lines. To a large extent this is prevented by the children having to take the general science course as well as the specific science course.

In addition to this it is necessary that the specific science course should be a science course in the true sense of the term and not simply a means of learning vocational techniques. Specialist science is all right so long as we insist on an understanding of scientific principles and methods.

There is no need for me to go into detail regarding these specific sciences. The general scope was given in chapter 2. Considering the difficulties of staffing, accommodation and equipment in many schools it is likely to be some years before these courses can be adequately organised and carried out. There is bound to be a certain telescoping of courses in many schools and as a result there must be, for a time, a certain amount of improvisation.

It is, of course, true that we shall never reach the ideal in education but we can approximate towards it. Improvements arise out of demands, so if teachers make the most of the facilities provided and suggest sensible additions and alterations, scientific education will move towards the ideal.

C. Allotment of Time

The amount of time devoted to science depends on the school and in particular on the wishes of the Head Teacher. Some few secondary modern schools may have no science at all; this is true of some girls' schools. They have domestic science but this is often not the kind of general science that is required. Its chief failings arise through the approach by way of the household organisation and also because of the large

gaps untouched in the field of science. However, in general, the time appears to vary between 40 and 160 minutes per week. Judging the curriculum as a whole, science can reasonably claim 120 minutes per week without the curtailment of other subjects.

This time can be divided in different ways. For outdoor Biology, it is useful to take the whole weekly allowance on one afternoon in order to give adequate time for the work. For indoor work, it may be preferable to have one period of 40 minutes devoted to a demonstration by the teacher or to simple practical work by the children, and 80 minutes for a practical period in which the children can carry out experiments. If the school uses a 10 day time-table, then Science could have two periods of 80 minutes each one week and one period of 80 minutes during the alternate week.

"There may be other variations in the time allowed for science based on the following considerations. If children are allowed to specialise in their last year, the children specialising in the science group of subjects (Mathematics, Science and perhaps Geography and Rural Science) may with advantage spend 160 minutes per week on General Science consisting of two periods of 80 minutes, or a whole afternoon in the summer for field work. Other children may perhaps do less science in their fourth year.

There may also be a variation in the time given to Science for the C and D children. For these children, it should be more informal and where convenient it is desirable to discard conventional time-table divisions. About 120 minutes per week can be considered a good average, but when there are favourable opportunities for the children to carry out field work this might well be increased to 150 minutes or a whole afternoon."[1]

In some schools science also has a place in periods given over to school societies (see chapter 10) and in social studies. The former provides an opportunity for a more recreational type of science and the latter for science treated as a cultural subject (see chapter 1).

Summary

A. Background Science.

1. See headings under Chapter 2 (A).
2. Relating the course to the environment (with examples).
3. The Concentric System.
4. Health and Human Physiology.
5. Syllabuses for C and D streams.

B. Specific Sciences.

C. Allotment of Time.

References (Chapter Four)

[1] O. Jones, *Modern Methods of Food Preservation* (Royal Institute of Chemistry, 1945.

[2] Models of Circulation and Respiration.

See *Science Masters' Book*, Series I, Pt. II (John Murray), pages 145-149.

C. Bibby, *An Experimental Human Biology*, Chapter 3.

[3] Apparatus to demonstrate Circulation and Respiration.

See *Science Masters' Book*, Series I, Pt. II, pages 149-154; Series II, Pt. II, pages 50-51, also pages 82-85.

Bibby, *op. cit.* Chapter 3.

[4] Films on Respiration and Circulation.

"Bronchial Tree". 16 si. Physiological Film Library, c/o C.F.L. (special permission has to be obtained from The Secretary, Physiological Society, King's College, The Strand, London). Loan charge.

"Circulation." 16 sd. C.B. Colour. Loan charge.

"Microscopy of the Circulation." 16 si. By Professor Florey: obtainable from Oxford University by special permission.

"White Blood Cells." 16 si. By Robin Weston of Simpl Ltd, London. Loan charge.

"Blood." 16 sd. G.B. Loan charge.

"Blood Transfusion." 16 sd. C.F.L. Free hire.

"Breathing." 16 sd. G.B. Loan charge.

[5] Film on "Elimination". 16 sd. G.B. Loan charge.

[6] Experiments on the Nervous System.

See R. J. S. McDowall, *Handbook of Physiology and Biochemistry* (John Murray), 1955.

C. Bibby, *Simple Experiments in Biology* (Heinemann), pages 124-135.

[7] Experiments on the Senses.

See Bibby, *op. cit.* pages 124-135.

J. A. Dell, *The Gateways of Knowledge* (Cambridge Univ. Press), 1912. 3s. 6d.

McDowall, *op. cit.*

[8] These syllabuses are embodied in the author's series of text-books, *Very Simple Science*, Books I, II, III and IV (John Murray).

[9] G. Nunn, "Science in the Secondary Modern School", *The School Science Review*, No. 111, March 1949, 154.

CHAPTER FIVE

SOURCES OF INFORMATION

The science teacher should have a good knowledge of science and should also know where to get information and other help. If his teaching is to be lively, he must be in touch with recent developments in science. His science must not be taken simply from text-books however admirable such books may be. Children are often aware that teachers get much of their knowledge from books. That source is bound to be one of the main sources, for teachers cannot find out all facts for themselves, nor are they on intimate terms with all the authorities for the various topics they bring into their teaching. What is important is that the sources from which the teacher gets his information are reliable and up-to-date.

After he has made his scheme, the teacher should gradually clothe these bare bones of a scheme with knowledge. This knowledge should include facts, useful anecdotes where appropriate, local information, experiments and certain practical points. From some text-books he can get all of these, but he must consider when he studies the text-book whether all the facts, for example, are correct. Many text-book writers must obtain much of their information from other books and it is humanly possible for them to copy mistakes or statements which are incomplete. Since science is primarily the search after the truth, it is probably more necessary in science than in any other subject to make certain that facts and information about the relationships between facts are correct. In what follows in this chapter I shall proceed to show how the best material for a science course can be obtained.

A. Local Sources

1. Scientific Societies

In most localities in this country there are local scientific societies. Mr K. Airey-Shaw has very kindly made a list of

the better known ones.[1] In this he has done a splendid piece of work. A teacher should get in touch with the local societies and join as many as he can afford.

He will find the members of these societies to be very helpful and ready to give every assistance. Almost any local society has a few experts along particular lines.

Local societies usually have meetings at regular intervals. Often they have lectures in winter and organised excursions in summer. For their lectures they sometimes rely entirely upon their own members if they happen to be strong societies, or they depend to a large extent on outsiders coming in to address meetings. In the better societies there is usually a vigorous discussion after a lecture. Lectures are often illustrated with specimens, lantern slides, pictures or films.

The summer excursions are usually designed to show members places of interest in the environment. They may include visits in which members do a certain amount of practical work such as the identification of flowering plants. It is usual to have guides to explain the interesting places included in the journey. These are often pleasant social occasions during which members get to know one another very well.

The better societies publish bulletins or perhaps an annual journal. The bulletins and journals should contain items of local interest, but of scientific value. It is not desirable for local journals to enter into competition with the more erudite national journals, which I mentioo later in this chapter.

To help in getting information for the bulletins and journals, there should be a panel of recorders attached to the society. These recorders are interested in different subjects and act as specialists. One may be a recorder for Mosses, another for Diptera and perbaps another for Archaeology. If a member has a doubt or difficulty about a certain moss, he should send the moss to the recorder for mosses, giving particulars about the moss and putting his query. Such particulars should include locality, habitat, date, name of person who found it and the names of any pests noticed. The recorder should not only answer the enquirer to the best of

4. MUSEUMS

The facilities which museums offer are not often fully appreciated. Most museums have much material behind the scenes in addition to the articles and material displayed in the show cases and in other ways for the general public. If a teacher shows himself really interested he will gain access to this material behind the scenes.

Some museums have a classroom set apart for classes, which can be brought from schools by the teacher. In such a classroom, the children can have instruction either from one of the museum personnel or from the teacher. The lesson should be illustrated with museum specimens. Teachers will find that the museum curator and his assistants are usually very helpful and will go to a great deal of trouble.

There are museums which lend out specimens and models to schools. This is a useful service, for the children are able to study such articles more thoroughly than they would be able to by an occasional visit to the museum.

A museum is also useful for the purpose of identifying specimens. The best museums for this purpose are the National Museums in London known as the Geological Museum, the Science Museum, the Natural History Museum and the British Museum. It is, however, only fair that a teacher should try to identify a specimen locally before sending it to London to one of the museums I have suggested. The Curators and their assistants in these places tend to be inundated with requests for information and whilst they try to help people, their time and patience are obviously limited.

Institutions like Kew Botanical Gardens,[2] Rothamsted Agricultural Institution,[3] Long Ashton Research Station,[4] and the Bureau of Animal Population[5] are useful for the identification of specimens appropriate to their special lines and for obtaining information. Here again it is desirable that they should not be troubled until local sources have first been tried.

Some museums, particularly the London ones, have excellent catalogues, illustrations and publications. The Natural History publications[6] are particularly useful for a

science course. These are often much cheaper than material produced by private enterprise.

It is also possible for science teachers to get special students' tickets so that they can study in the research departments of the national museums. This gives teachers not only a good opportunity of looking up information and studying specimens for themselves, but also for consulting experts in particular fields.

5. Industries

Industrial undertakings are often ready to help teachers. Sometimes it is propaganda on their part either to sell their products or to get employees, but if the information they supply is of use to schools then it is advisable to get it. I will quote two personal examples.

Since coal gas appeared in my science syllabus I considered it would be a good thing if I could get samples of the by-products to show to my children. I approached a well-known gas undertaking and was supplied with a cupboard with glass doors containing glass stoppered bottles containing samples of about 60 of the by-products from coal.

In my syllabus also appeared the subject soap. After my success with the coal by-products, I thought I would try my luck with soap. So I wrote to a well-known manufacturer of soap and received samples of the raw materials from which soap is manufactured. Again, the samples were packed in well-stoppered bottles.

Teachers will find that they can do this kind of thing. In addition to specimens, they will be able to get charts, pictures and booklets. They should also not forget the possibility of taking science classes round industrial works.

6. Services

Information can also be obtained from Water and Electricity Undertakings, from Sewage Disposal plants, from Municipal Road Making[7] departments, from British Railways,[8] from Canal Transport departments, from the Post Office and from Shipping firms. Of course, Gas is another service, but I have already mentioned it.

There is far more science in these undertakings than many people are aware of. Consider road making. In the past when the speed of travel was comparatively slow, roads did not need to be so level or so straight. Now when cars move quite quickly it is primarily essential that the main roads should have level surfaces. It is also desirable that they should be straight where possible but if they have to curve, then the road should be cambered so that no great reduction in speed is necessary in going round a curve. The road must also be capable of standing up to heavy wear and tear and of wearing evenly. Further, the road should be well drained and should not get slippery. All these points have to be considered and it is true to say that the Department of Scientific and Industrial Research is carrying out some useful work in this direction.

Again use should be made of visits to these places because there is so much science to be learned there which to the children will be vital knowledge worth knowing.

B. National Scientific Societies

At the end of this chapter* I have given a list of scientific societies which can be considered national and useful to teachers. It is desirable for a teacher to be a member of as many of these as he can afford. He may not have the time to devote himself to all those he becomes a member of, but such membership has distinct advantages which I shall enumerate.

Supposing he joins the British Ecological Society to take an example. He finds that in the society are the best Ecologists in the country. There are also Biologists, Botanists, Zoologists, Entomologists, Geneticists, Bryologists and other specialists. If he goes to a meeting he can converse in a friendly association with leading authorities. He might have a cup of tea with a botanist of international standing. He will find that these experts far from being aloof are very friendly and will help him without patronising. This, in my opinion, is the best reason for joining such a society.

Another reason is that the teacher is able to receive the journals produced by the society. These journals consist of

original articles based on research. These articles may vary in quality but they do give teachers an insight into the methods of modern research workers. They are often difficult to understand, largely because there are no trimmings and because they embody the results very often of years of patient work. When, however, the reader has mastered the contents of one of these original papers, he will feel inspired and prompted to think along new lines. For a teacher this is one of the best things that can happen to him. What teachers can learn from people who are not teachers is so valuable because it is like letting light in from without. There is a tendency for teachers to be conservative in their ways and mixing with other teachers is often of little inspirational help. By joining a society like the British Ecological Society they will get this inspirational help because they will mix with people in other fields doing work which is often just as important as teaching.

It must also be remembered that a teacher should be prepared to take an active part in a society. He may be able to read a short paper of some original work he has been doing either alone or with his children. There is also an opportunity for him to get something published in the journal. Since scientific journals demand a very high standard of achievement, he has to work hard in order to produce something worth while. This is very good training for him.

C. Information from Government Sources

The information which can be obtained from Government sources has been partially covered previously. Mention was made of the National Museums and of the Post Office. Also reference was made to Nationalised Services and Industries.

There is a valuable source of information that has not been considered previously and that is H.M. Stationery Office.[10] This Government Publishing Department produces some very fine material at very reasonable prices. That issued by the Ministry of Agriculture and Fisheries is a remarkably fine series. Every school should possess many of these, which deal with such diverse subjects as Insect Pests of Fruit Crops,

Weeds of Arable Land, Bees, Certain Birds and Potatoes. Then there are the publications of the Forestry Commission[11] which deal with such subjects as Mosses of Forests, Forest Trees and Wood-boring beetles.

H.M. Stationery Office produces periodic lists of recent publications. These have included, for example, an excellent publication on Birds in London. There have been fine reports on National Parks.

D. Information from Private Enterprises

This has to some extent been covered previously. Teachers should explore all possible avenues for scientific information. The author has obtained good knowledge from such enterprises as an oil refining company, a motor car manufacturer, a vitamin manufacturer, a producer of fine chemicals, and a glue firm.

It should be mentioned here that it is often possible to get useful information from catalogues of various kinds. The apparatus catalogues which need to be obtained for laboratories often contain useful information.

E. Reports of Research Institutions

Research institutions of various kinds issue reports which can be bought or read in good libraries. Just let me mention a few.

The Freshwater Biological Association[12] produces an annual report which gives a useful account of their work. The Headquarters of this Association is at Wray Castle on Lake Windermere and consequently much of the research on water biology takes place in this lake. This association is rendering a valuable service to the country. The work has an economic side in that they are making a study of freshwater edible fish types.

Peter Scott's Bird Sanctuary[13] known officially as the Severn Wild Fowl Trust produces a beautifully illustrated report of the work of the Trust. The work is carried out at Slimbridge in Gloucestershire on the south bank of the River Severn. On this sandy bank in winter are to be found thou-

sands of wild geese which have migrated from cold regions such as Iceland, Norway and Siberia. These birds are studied most thoroughly and very valuable research is carried out in connection with migration. This is all detailed in the report and the illustrations consist of photographs and drawings. The drawings are usually by Peter Scott, the Director.

Rothamsted[14] Agricultural Institution issues a very interesting annual report in which mention is made of the diverse types of research being carried on there such as work on crops, bees, pigs, effect of length of daylight on growth of crops, and agricultural statistics.

F. National Libraries

These have been mentioned before. It should however be noted here that teachers can consult books in National Libraries. If they happen to be members of certain Scientific Societies[15] they are privileged to borrow books from the Science Library, South Kensington. This is a very comprehensive library from which students can borrow books far too expensive to buy in large numbers.

Since most of the national reference libraries are situated in London, it may mean a visit to London in order to read certain books, unless they can be borrowed through the Local Municipal Library.

G. Journals

A member of a society receives the journals of that society automatically. For other journals he will usually have to visit a good reference library, preferably a University Library. A group of friends might collaborate and arrange to buy a set of certain journals between them. Since journals have a very limited sale, they are usually expensive.

H. Reports from other Schools

Why is it that schools exist so much on their own? So often their only contacts with other schools are at inter-school matches or sports.

I feel that schools have much to give one another by way of exchanging information and experiences. How can this help Science in Secondary Modern Schools?

If a number of Secondary Modern Schools in an area have Scientific Societies why not arrange some joint meetings either indoors or in the form of an excursion? There is so much to be gained by this kind of activity. Consider two schools, one of which is near an oak wood and the other a lake. The school near to the oak wood could arrange a joint excursion to the oak wood and by way of a return meeting, the other school could arrange for the study of the lake with perhaps a sail on the lake as an added attraction. One school may have got together an excellent collection of butterflies and moths, whereas another has a good collection of beetles. By interchange visits, the children not only learn a great deal about what the other school scientific society is doing but also is inspired to new efforts.

I should like to see schools linked scientifically particularly through an organisation already in being.[16] School science will gain in strength as a result. There are certain collective problems such as butterfly migration, the study of the habits of badgers, the study of harvestmen, which is best done collectively. When you read Watt's *School Flora*[17] it is evident that some joint work of this kind has been done by a certain group of Public Schools in connection with plants. What has been done in a small way could well be extended.

I look forward to the time when projects will not merely involve one school working independently, but will be organised by committees representative of a number of schools over a wide area. Such projects can really come to mean something and have genuine scientific value. So often school projects are very transient efforts. A co-ordinated piece of research work carried out over a wide area by different schools could be a real inspiration to education and a substantial contribution to truth.

Summary

A. Local Sources.

1. Scientific Societies.
2. People.
3. Libraries.
4. Museums.
5. Industries.
6. Services, e.g. Water, Gas, Electricity, Sewage Disposal, Road Making, Railways, Canals, the Post Office, etc.

B. National Scientific Societies.

C. Information from Government Sources.

D. Information from Private Enterprises.

E. Reports of Research Institutions.

F. National Libraries.

G. Journals.

H. Reports from other schools.

References (Chapter Five)

[1] H. K. Airey Shaw, *Directory of Natural History Societies* (Amateur Entomologists' Society; 1 West Ham Lane, London, E.15), 1948. 7s. 6d.

[2] *Royal Botanic Gardens, Kew, Richmond, Surrey.*

[3] Rothamsted Experimental Station, Harpenden, Herts.

[4] Long Ashton Research Station, Bristol.

[5] Bureau of Animal Population, 91 Banbury Road, Oxford.

[6] Natural History Museum Publications, Natural History Museum, Cromwell Road, London, S.W.7.

[7] Film "Road Tar". 16 sd. Department of Scientific and Industrial Research, Park House, 24 Rutland Gate, London, S.W.7.

[8] Film showing stresses and strains in a railway line. (British Railways.)

[9] *List of the better known Scientific Societies suitable for Science Teachers:*

Freshwater Biological Association of the British Empire: The Ferry House, Far Sawrey, Ambleside, Westmorland.

Society for British Entomology: Lt.-Col. F. C. Fraser, 55 Glenferness Avenue, Winton, Bournemouth, Hants.

Association of School Natural History Societies (Honorary Secretary: David Stainer): Salisbury House, St Thomas' Hill, Canterbury, Kent.

Council for the Promotion of Field Studies: Secretary and Treasurer: Mr A. G. T. Oakley, Balfour House, 119/125, Finsbury Pavement, London, E.C.2.

School Nature Study Union: Hon. Subscriptions Secretary: Dr Winifred Page, 5, Dartmouth Chambers, Theobald's Road, London, W.C.1.

Forestry Commission: The Secretary, H.M. Forestry Commission, 25 Savile Row, London, W.1.

Department of Scientific and Industrial Research: Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.

Amateur Entomologists' Society: 1 West Ham Lane, London, E.15.

Royal Entomological Society of London: 41 Queen's Gate, South Kensington, London, S.W.7.

Royal Astronomical Association (Secretary: Mr M. W. Ovenden, The Observatories, Madingley Road, Cambridge).

Royal Microscopical Society, B.M.A. House, Tavistock Square, London, W.C.1.

Royal Horticultural Society: Vincent Square, London, S.W.1.

Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth.

British Trust for Ornithology, 91 Banbury Road, Oxford.

Science Masters' Association (General Secretary: Mr F. L. Swift, The Salt School, Shipley, Yorks.).

Association of Women Science Teachers (Secretary: Miss L. E. Higson, 11 Fillebrook Hall, Fillebrook Road, Leytonstone, E.11).

Royal Institute of Chemistry (Secretary and Registrar: 30 Russell Square, London, W.C.1.

The Linnean Society: Burlington House, Piccadilly, London, W.1.

Physical Society: 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

Zoological Society: Zoological Gardens, Regents Park, London.

British Ecological Society (Correspondence to: Mr E. D. Le Gren, The Ferry House, Far Sawrey, Ambleside, Westmorland.)

Universities Federation for Animal Welfare: 7A Lamb's Conduit Passage, London, W.C.1.

[10] H.M. Stationery Office, York House, Kingsway, London, W.C.2.

[11] Forestry Commission. See Note 9.

[12] Freshwater Biological Association. See Note 9.

[13] The Severn Wildfowl Trust, New Grounds, Slimbridge, Gloucestershire.

[14] Rothamsted Experimental Station. See Note 3.

[15] E.g. Royal Institute of Chemistry. See Note 9.

[16] Association of School Natural History Societies. See Note 9.

[17] Watt, *School Flora* (Longmans Green & Co.) 5s. 6d.

CHAPTER SIX

ACQUIRING TECHNIQUES

A. Traditional

The teacher has to acquire skill in science and so have the children he teaches; how far the skills he himself learns are taught to the children will depend on their capacity at a particular time. As is well known, the capacities of children depend at least upon age and intelligence. The teacher must judge for himself what the children are capable of doing.

1. Handling of Apparatus and Chemicals

The first technique I wish to consider is that of handling apparatus. Lord Rutherford could not tolerate assistants who were often breaking pieces of apparatus. This no doubt was because they lacked the skill of handling apparatus not because of the expense, though that is a factor. The skilled scientist has a way of handling apparatus so that he rarely breaks anythiog. It is noticed with tyros in science that they usually break many pieces of apparatus at the beginning. Some of these breakages are due to not applying common-sense. I have seen such people heat a stoneware pneumatic trough over a naked Bunsen burner flame or heat a test-tube, with a wet outer surface, over a flame, with the expected result in both cases of a breakage. In practical science one of the first techniques a beginner must learn is the handling of simple forms of apparatus: he should not at the outset be trusted to use more elaborate apparatus.

There are two or three elementary principles concerning the use of chemicals. No more of a substance should be used than is actually required, and if any which has been taken from the bottle is not used, it should not as a rule be returned to the bottle, because it may no longer be pure. Chemicals should always be treated with the utmost respect since some of them are very dangerous. They can be dangerous in a number of ways. Some, like mercuric chloride, are

poisonous, some, like sulphuric acid, are corrosive, some, like ether, are inflammable and some, like picric acid, are explosive. No child in a Secondary Modern School should use a chemical in one of these four dangerous categories. It is desirable to keep all chemicals of this type in a locked cupboard. It seems to me foolish to view a poison cupboard with such concern and forget chemicals in these other dangerous categories. From the point of view of a teacher, it should be part of his scientific knowledge to know how to look after chemicals. He should, for example, know that white phosphorus must be kept under water; that sodium should be immersed in a liquid like naphtha or petroleum; that picric acid should always be well mixed with water; that inflammable liquids like ether, benzine, petroleum ether, xylol, and carbon disulphide should be kept in cold places and in gas tight bottles preferably glass stoppered.

Other elementary points are these. Bottles of chemicals must always be labelled and if paper labels are fixed they should be waxed to prevent them getting dirty or corroded. If the bottle contains a solution, the approximate strength should appear on the label. When liquids are poured from bottles they should always be poured away from the labels.

When making up solutions, it is always desirable to make a quantity which will last at least six months unless it is unstable, when a small quantity can be made. Aqueous solutions should always be made with distilled water. A science teacher would be wise to get a copy of the Scientist's Diary.[1] This gives all the data he requires for making up solutions. There are suitable strengths for laboratory reagents and they should be adhered to; science must never be haphazard.

With regard to the storing of chemicals on shelves, it is desirable to arrange inorganic substances in alphabetical order according to the basic radicals. Also arrange acids in alphabetical order; corrosive acids being placed in bottles on porcelain trays. Solutions of reagents should be separate and again in alphabetical order according to the basic radicals. Keep sodium and potassium hydroxide solutions in bottles with corks, not glass stoppers. It has been found that if a glass stopper is used, a thin layer of the carbonate of the

respective metal forms between the sides of the stopper and the neck of the bottle, and this tends to cause the stopper to stick so tight as to be irremovable.

There are certain kinds of apparatus which require special handling. Delicate apparatus should be kept in drawers or cupboards and rest on cellulose cotton wool. This type of cotton wool is better than ordinary cotton wool, because it does not stick to the glass-ware. I would suggest that such items of glass-ware as pipettes, burettes, dropping funnels, carbon-dioxide bulbs and Liebig's condensers be kept in this way. Keep expensive types of apparatus such as voltmeters, ammeters, delicate galvanometers, mounted frogs' skeletons, models of eyes, and microtomes in locked cupboards.

Teachers ought to be able to render simple repairs to galvanometers and derived instruments such as the ammeter and voltmeter. It is useful to take an old instrument of this type to pieces so that the experience gained will be useful when a genuine repair is necessary. In a laboratory where physics is carried out, it is useful to have a mirror galvanometer for demonstration purposes. The galvanometer itself should be at the back of the class room and the scale and lamp should be near the blackboard so that readings can be seen by all members of the class.

A teacher should get in the way of handling lenses and mirrors so as to be able to fit up light ray apparatus. He must discover methods of improvisation such as that of using a small tin can as a lampholder for 12 volt lamps; and cylindrical beakers of water as a means of obtaining parallel rays of light. With the aid of strips of brass and metal rulers he can make adaptable optical benches. With two metre rules hinged together he can make a simple spectrometer. Small squares of zinc can be perforated or slits can be cut in them to obtain the necessary beams. Combs can be used to split up parallel beams of light into narrow rays.

The science teacher in a school should be able to fit up pieces of apparatus with a Liebig's condenser for distillation with adaptations using a fractionating column, reduced pressure and steam distillation. He should also be skilful

in fitting up a reflux condenser. It is sometimes necessary to use water baths or oil baths.

2. General Quantitative Techniques

Then there are the measuring instruments to consider. Balances have to be checked and also burettes, graduated cylinders, pipettes and measuring flasks. The markings have to be made visible when they become indistinct.[2] It is particularly desirable to clean measuring vessels with chromic acid[3] to remove all traces of grease.

This leads on to the subject of general quantitative technique. The most accurate piece of apparatus in the laboratory should be the best balance. In order to keep a certain standard of measurement in the scientific work carried out in the laboratory, it is necessary for the science teacher only to use the best balance. The set of weights to be used with it should correspond in accuracy with the balance. Such a balance should be of the analytical type and will be in a glass case. It should be kept dry with silica gel in a special container.[4] Concentrated sulphuric acid is considered by most people to be better, but it is rather dangerous to have in a balance case in school. All other kinds of measuring instruments can be checked from the balance. Spring balances can be checked with the balance weights. Volumetric pieces of apparatus can be checked by weighing the water they contain at definite temperatures by the methods described in many books.[5]

A teacher should not only be able to weigh materials for himself, but he should also be able to teach children to do the same. He must be on his guard with regard to children adding weights to a chemical balance whilst the balance arm is raised. Chemicals are likely to be put directly on the balance pans if the children are not tutored correctly.

A science teacher ought to be acquainted with methods of titration. This particular technique has made great strides during the last ten years. In titrations depending on reaching a definite *p*H value there are a number of indicators to choose from according to the *p*H required.[6] A teacher should know which to use for an experiment. He should also know

when to have the indicator in the actual solution and when to carry out spot tests. Although he may not need to bring specialised titrations in his actual teaching, it would be useful if he were familiar with the uses of potassium permanganate, potassium dichromate, iodine, sodium thiosulphate.

It is desirable that he should be familiar with the electrical method of titration in which a sensitive galvanometer (often called a *p*H meter) indicates the end point.

3. Training in Observation

A scientist must be a good observer. One who teaches science should be quick to notice small points and should train those he teaches similarly. A number of scientific discoveries have been the result of observations that would probably have been missed by one not trained in science. Faraday noticed drops of liquid in a tube which had contained gaseous chlorine and which had been cooled under pressure. This was liquid chlorine, but would probably not have been noticed by most people. Ramsay's discovery of the inactive gases and the identification of specific gases was the result of very careful observation. When oxygen, nitrogen, carbon dioxide and water vapour had been removed from the air, he discovered that there was still a small fraction of gas unidentified. This he was able to separate into the component inactive gases.

4. Scientific Calculations

An understanding of methods of scientific calculation is desirable. In these days this involves a knowledge of statistical analysis.[7] One of the important parts of the analysis of results is to decide what results are significant. There is much loose thinking about figures obtained in experiments. Not only have we to decide the limits of experimental error, but also we must be careful not to come to conclusions unwarranted by the results obtained. Involved in this is the question of how many significant figures arise in an answer obtained. As much of this technique as possible should be passed on to children, particularly the A children. How often laborious long division is carried out to obtain a figure

such, for instance, as 12.7321 when an answer of 13 would have given all the information required or warranted by the accuracy of the experiment.

5. Special Biological Techniques

There are a number of biological techniques which a teacher should learn. These are described in a number of good books.[8] I would, however, recommend the following techniques as a beginning. The science teacher as part of his training ought to learn how to carry out dissections of types from small animals like the cockroach to medium animals like the rabbit. He should learn how to dissect plants. If he has not done this kind of thing at college, it is desirable that he attends an evening course or residential course to learn this technique. The same argument is applicable to slide making, because it is not possible to learn the technique from a book. If the teacher learns the rudiments of section cutting, dehydrating, staining and mounting, he will for himself be able to try out new stains, new dehydrating agents and different methods of mounting. A science teacher will find it very useful to be able to make slides, not because he can make better slides than he can buy, but because he can make slides of interesting material discovered on nature rambles and on other occasions. The teacher may wish to carry out some experimental work involving slide making; his knowledge of slide making will then be very useful.

If he becomes keen on slide making, the science teacher may wish to carry out more difficult work such as slides made of animal sections which have had to be prepared through wax impregnation. This is necessary for making slides of say a set of a frog's organs like the stomach, liver and testis. There are also special techniques in connection with many other specimens such as blood films, mounting obelia, amoeba, foraminifera, diatoms and algae.

Other useful biological techniques which a teacher might learn are preparation of skeletons,[9] the mounting of insects,[10] preparation of cultures[11] and simple bacteriology.[12] It seems to me to be foolish for schools to order skulls of rabbits when they can be prepared comparatively easily. The mounting

of insects is something which is often badly done in schools, yet when insects are correctly mounted they look very well indeed. Concerning the mounting of insects, the important points are: how to collect the insects; how to kill the insects; when to relax; when to set; and how to place in the storage box or cabinet. I have included the collection of insects in the matter of mounting the insects, because so many insects are ruined in the collecting. The preparation of cultures is useful for such plants and animals as moulds, amoeba, paramecia, volvox, daphnia and cyclops. It is useful to have a thermostatically controlled container for this work, because it often happens that fluctuations of temperature will kill off some of the cultures such as paramecia. The culture of bacteria requires the use of some kind of sterilising chamber for the petri dishes, boiling tubes, culture media and other apparatus. Various cultures can be tried out.[11]

6. Special Rural Science Techniques

There are also various techniques to be used in connection with the application of the science in the school garden and livestock. It is useful to know something about plant culture in aqueous media (hydroponics); dealing with the products of variety trials; and sectioning of eggs from the incubator and the permanent mounting of these. The subject of plant culture in aqueous media has been extended to include the use of sterilised sand. This is rather better because of its holding properties. Plant pots have to be coated with bitumastic so that the plants do not get nutrients from the actual pot. There are formulae for special culture solutions to be added to the sand.[12]

In connection with variety trials, there are the special methods of sampling so as to get a representative sample of the seeds or the products to be considered. There is also the technique of recording including not only the time factor but obtaining data regarding daily soil temperatures as well as air temperatures; rainfall; hours of sunlight; and composition of the soil. There is the matter of weighing the sample. Finally there is the matter of working out calculations and drawing conclusions.

The sectioning of eggs and the preparation of chick embryos at various stages is a useful technique. It is good for the children to see the chick embryo in its early stages, say after 48 hours, when the beginning of the heart is evident in the pulsating red dot. A complete set of embryos can be obtained and set up in the school science museum.

B. Less Traditional

1. Use of Wood-work and Metal-work

It is usual now for the science department of a school to contain wood- and metal-work benches and the appropriate tools. These should encourage the teacher of science to learn wood- and metal-work. He will find facility in these crafts of inestimable value in his work as a science teacher. There is much apparatus which he can make either as demonstration material or for the children's use.

The teacher with initiative would never entirely rely on apparatus supplied by manufacturers. Whilst much of this is good, it can never meet the needs of the enthusiastic teacher. He may wish to try out a special kind of butterfly net, or he might think of an experiment to show how the speed of light can be measured or he might work out a demonstration experiment to show the three methods of heat transfer as conduction, convection, and radiation.

In many districts there are courses in wood and metal-work which a teacher can attend. He can also get ideas from these courses and from books[14] as to which tools, wood and metal to requisition.

2. Glassblowing

Skill in glassblowing is another useful adjunct to science teaching. So often does a teacher want a glass bulb in a special place in a tube or a joining between two tubes to make a T or Y; or a joining between a narrow tube and a wide tube. If he has had some practice in glassblowing and become adept at the essential skills in this craft, he will be able to fit up some useful pieces of apparatus. Consideration of facilities for this work in the laboratory is dealt with in

chapter 13. As with wood- and metal-work it is desirable for teachers to attend a course on this subject in order to get the full benefit from books about it.[15] It is sometimes necessary to fit platinum electrodes through glass, and this can be done quite easily with a little practice. I would say that the main stages along the highway to success in glassblowing are: (1) some understanding of the properties of the different kinds of glass; (2) practice with the blowpipe-flame, trying different nozzles and mixtures of gas and air; (3) acquiring steadiness in rotating glass tubing in the flame; (4) skill in blowing, puffing and sucking in manipulation; (5) learning how to cool glass after it has been worked; and (6) acquiring the art of getting finish in the article being made.

3. Lantern Slide and Film Strip Making

Lantern slide and film strip making are dealt with in chapter 12.

4. Photomicrography

The last technique I wish to consider is Photomicrography. Sometimes a teacher may wish to produce a permanent photographic record from a prepared slide. He can do this by photomicrography. In fig. 5 I have illustrated a useful

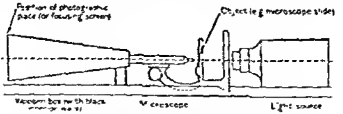

Fig. 5. Apparatus for Photomicrography.

type of apparatus for this purpose. This works quite well and is inexpensive. The microscope used should be the best in the school since the finished result can only be as good as each component and there are more variations in microscopes than the other components. Use the brightest light source and make sure that it gives even illumination otherwise the photomicrograph will not be good. Variations in the intens-

ity of the light field can be seen in the ground glass screen. Slides used for photomicrography should be very good in quality; when arranging to take a photomicrograph move the slide until you get the best possible view. Definition is of very great importance in this kind of photography. This is often made difficult by the fact that the section on the slide usually consists of more than one layer (say of cells). In this case it is necessary in the focusing to get that plane in focus of which detail is required in the photograph. As another aid to sharp focus, always use the largest negative that the apparatus will accommodate. It is, of course, obvious that if a photograph has to be enlarged, defects will be enlarged as well, so that the less enlarging is done the better the definition for a given negative. Plate I (Frontispiece) is a photograph taken with this type of apparatus.

Experiments should be tried in photomicrography using colour filters. It is useful in this connection to consult a good book on the subject.[18] Colour filters are particularly necessary when using stained sections. The aims of the colour filters are to give the best definition and correct rendering of true values. For example, in a section stained predominantly red; the use of a green filter would make all the red seem black and this would give good definition in the part stained red.

With regard to the types of plates; those that give good definition of the panchromatic variety are the best. High speed plates are not required. The time of exposure is attained largely by a combination of judgment and trial. It is desirable to use a good light source as this not only shortens the necessary exposure, but also tends to give better definition. With a little care and practice some good results will be obtained.

Summary

A. Traditional:

1. Handling of apparatus and chemicals.
2. General quantitative techniques.
3. Training in observation.
4. Scientific calculations.
5. Special biological techniques.
6. Special rural science techniques.

B. Less Traditional:

1. Use of wood-work and metal-work.
2. Glassblowing.
3. Lantern Slide making and Film Strip making.
4. Photomicrography.

REFERENCES (CHAPTER SIX)

[1] The Scientists' Reference Book and Diary published by James Woolley Sons & Co. Ltd., Manchester.

[2] See Woollatt, *Laboratory Arts* (Longmans).

[3] See Treadwell, *Quantitative Analysis* (Wiley).

[4] Silica Gel Desiccator: can easily be regenerated and lasts indefinitely; obtainable from Silica Gel Ltd., Bush House, Aldwych, London, W.C.2.

[5] See Treadwell, *Quantitative Analysis* (Wiley).

[6] See B.D.H. list of Indicators.
Also A. Findlay, *Physical Chemistry* (Longmans).

[7] See H. Levy and E. E. Preidel, *Elementary Statistics* (Nelson). 5s.

[8] See list of books at the end of Chapter 11.

[9] H. L. Green, *Zoological Technique* (Allman).

[10] See pamphlets of the Amateur Entomologists' Society.
Also *Instructions for Collectors: Insects.* British Museum (Natural History).
Also Duncan and Pickwell, *The World of Insects* (McGraw Hill).

[11] See *Science Masters' Books*, Series I, Vol. II; Series II, Vol. II (John Murray).

[12] Henrici, *The Biology of Bacteria* (D. C. Heath & Co.).

[13] Obtainable from Long Ashton Research Station, Long Ashton, Nr. Bristol.

[14] *A Woodwork Notebook* (Cassell & Co. Ltd); *A Metalwork Notebook* (Cassell & Co. Ltd).

[15] See M. C. Nokes, *Modern Glass Working and Laboratory Technique* (Heinemann).
W. E. Parke-Winder, *Simple Glass Blowing for Laboratories* (Crosby Lockwood).

[16] See R. M. Allen, *Photomicrography* (D. Van Nostrand Co. Inc.).
Also *Photomicrography* (Kodak).

CHAPTER SEVEN

APPARATUS AND MATERIALS

In the book, *The Teaching of Science in Secondary Schools*,[1] there is a very good chapter on Apparatus and its maintenance. This as well as the other chapters in this book should be read by all teachers in Secondary Modern Schools. Since, however, this book applies to Secondary Grammar Schools rather than to Secondary Modern Schools, there are certain matters to be considered which more especially apply to the Secondary Modern School.

A. What Should a School Requisition?

This question can only be answered after a consideration of the following points:

1. Scheme of work.
2. Time spent on science.
3. Proportion of demonstrations and class laboratory work.
4. Knowledge and ability of the teacher.
5. Finance.
6. Storage space.

Let me consider these in turn.

1. *Schemes of work* were fully considered in chapter 4. Here I will simply relate it to the matter of apparatus. It is obvious that the apparatus and materials should be adequate to provide demonstrations and class practical work for the children. If any teacher is foolish enough to ask for materials outside the scope of the syllabus, the apparatus becomes so much lumber taking up valuable space as well as causing unnecessary expense. A laboratory at the outset should be equipped with a basic outfit of equipment and chemicals similar to that given at the end of this chapter. This list has been compiled with the highest common factor of needs in view. I suggest that a Local Education Authority should provide the laboratory with such an outfit at the beginning

and not expect the items to be provided out of the annual capitation allowances. However, I will say more about this later.

2. The amount of *time spent in science* affects the amount of apparatus and materials. The quantity of chemicals used and the amount of apparatus consumed is roughly proportional to the time spent on science, provided the science course is largely experimental.

3. The amount of equipment must also depend on the proportions of *time spent on demonstrations and practical work* by the children. When ordering for class use, you have to consider 30 children carrying out practical work at the same time. I would suggest that it is not necessary or even always desirable for a class of children to be doing the same experiment at the same time. This was considered in Chapter 3, section C(3). Considerable saving in expense is possible and also improved variety of experiments by this method. You would not consider ordering dozens of clinostats, auxanometers, Wheatstone bridges and Post Office Boxes for example.

4. *The knowledge and ability of the teacher* are matters often overlooked even by the teacher himself. It is no use, for example, asking for a glassblowing bench complete with blowpipe, bellows and tools, if the teacher is not skilled in glassblowing or prepared to learn the art. It is no use a teacher ordering stains which he knows nothing about and is not therefore likely to use. A teacher should always make sure that what he orders he can use effectively.

5. *Finance* to some extent controls the amount and quality of the equipment for a laboratory. If, as I have suggested, the laboratory receives a basic supply of equipment at the outset and the annual capitation grant can be used for adding to this and making good any breakages, the science teacher is in quite a favourable position. He need not get all the equipment to carry out the syllabus at the outset. If he is starting with a new syllabus there appears to be every good reason to give each A form (1st, 2nd, 3rd and 4th years), each B form, each C form, and each D form the same syllabuses (A, B, C or D) for the first year the syllabus is running. The

next year will then see the first year schemes applied to the newcomers, now Year 1, and the second year schemes to Years 2, 3 and 4. In this way the scheme can be better implemented than by the common practice of attempting to carry out the scheme as it stands during the first year. By this means, the teacher can not only equip the laboratory more suitably, but he can also work out the details of the scheme more thoroughly. This method will enable the teacher to meet all his needs out of the annual capitation allowances. He can as a rule buy better quality materials. *Scientific apparatus varies so much in quality that it is often* advisable to consider the matter very carefully. The cheap article is not always the cheapest in a long term policy. Good reagent bottles are better than cheap corked bottles with inconspicuous labels; good glass-ware (e.g. Pyrex) is better than nameless glass articles; good quality voltmeters are better than cheap ones and good microscopes by firms specialising in microscopes are better than cheap instruments termed microscopes but not worthy of the name. The same remark applies to chemicals. Commercial chemicals may be cheap, but for most experimental purposes in any laboratory are useless. They can be dangerous. When making oxygen by heating potassium chlorate and manganese dioxide together, it is most important that these components should be pure, otherwise an explosion[1] may result. It is therefore desirable that requisitions should be made out carefully with adequate specifications and ordered from firms of repute. Do not, for example, be vague in this way:

12 nests of beakers

but more specific:

12 nests of beakers, each nest containing:
1 50 ml., 1 250 ml., and 1 1000 ml. Pyrex
squat form beaker with spout (cat. No.)

6. *Storage Space.* It is important that there should be enough storage space for the equipment ordered. If at the time of ordering, it is known that the storage space is inadequate for what is ordered, then endeavour at the same

time to prepare provision for the apparatus when it comes by requisitioning a cupboard or arranging for space to be provided in some other way.

Breakages often occur through apparatus being badly stored. Method in storing is important in any subject, but probably more so than ever in science. Equipment and materials should be arranged so that items can be found quickly. Those that are required often should be more readily available than those seldom used.

B. Making of Apparatus

This subject is also considered in chapter 9 from the point of view of the correlation between Science and Wood- and Metal-work. There are other aspects which can be dealt with here.

However eager a science teacher may be, his time is limited for making apparatus. Since a science teacher has to spend so much of his time in the preparation of experiments, he should have a liberal amount of time in school hours for this work. It is not easy to specify how much he should have, but I think the time for scientific preparation should be at least equal to the time spent on actual science lessons. It would be a great help to the science teacher if he had a laboratory assistant. This, however, is not a simple matter for the Local Education Authority for a number of reasons. The post of laboratory assistant should *not* be a dead end, *i.e.* the assistant should have a chance of learning science whilst he acts in this capacity so that his work can lead to promotion. There should be opportunities for him to study either for a B.Sc. degree or for the Higher National Certificate. Also there must be some supervision of his work during school holidays. It seems that if science teachers want laboratory assistants, they should be prepared to spend part of their holidays in supervision. Surely it is agreed that whereas school holidays are a rest from teaching they are not expected to be entirely devoted to pleasure, but at least partially to teaching preparation. This thought may not be popular with some teachers; but I cannot visualise the successful teacher spend-

ing 12 weeks of the year in idle pleasure. He will surely devote a good proportion of it to improving himself as a teacher. So why should the science teacher not spend some of his holidays supervising the laboratory assistant and also doing some science preparation himself?

If the science teacher wants a laboratory technician and not just a cleaner-up and bottle-washer, that is what he should be prepared to do.

With the help of a laboratory assistant a good deal of apparatus can be made and much can be assembled from manufactured parts. I will suggest some forms which can be usefully made.

1. Microprojector

A perfectly serviceable microprojector can be made with a microscope and a lamp source (see fig. 6). It is essential to

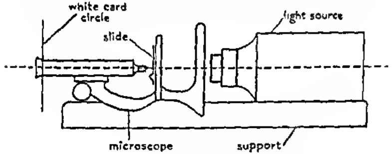

Fig. 6. Microprojector.

use a bright light source which should be central with the microscope optical axis. An old lantern serves the purpose very well. The lens system of the lantern is removed and if necessary a modern pointolite screw cap bulb of about 500 watts is fitted. The microscope is better with a condenser, because this improves definition. It is important to mount the microscope so that it does not wobble and to cover the apparatus with metal sheeting bent appropriately where light escapes. An additional light shield round the eye-piece see fig. 6) is an additional help to good screen definition. You can by this means get a brilliant image of a transparent

section or object with a $\frac{2}{3}$ inch objective (N.A. 0.17) and a good image, though less brilliant, with $\frac{1}{6}$ inch objective (N.A. 0.65).

2. Wheatstone Bridge

Why schools buy Wheatstone bridges when they are so easily made I do not know. All that is required are a good baseboard, strip brass about $\frac{1}{2}$ inch wide, terminals, a metre length of resistance wire, a metre-rule, and some odd pieces of metal to make a jockey. When the parts are assembled they make a Wheatstone Bridge just as efficient as one that is bought. The only part which presents any difficulty is the jockey which requires more skill in its making than the rest of the bridge.

3. Potentiometer

This is simpler to make than a Wheatstone Bridge, because it is essentially a component part of the bridge. It should be possible to make half a dozen of these at the same time.

4. Light Ray Apparatus

The main part of this is the light source and the lens system to provide a parallel beam of light. A laboratory should be fitted with a 12 volt supply (see chapter 13) and the light ray is best made to work off this supply. The apparatus can either be in units consisting of a lamp fitted in a reflector, cylindrical lenses in holders, metal plates with slits and holes, plane and spherical mirrors and prisms; or it can be made in a more permanent form. In the more permanent form some kind of optical bench should be made as a basis so that the other components can be fitted on. The simplest would consist of two hinged metre rules. Lens and mirror stands can be made to clip on the end of the rules. The rules provide ready means for measuring distances.

5. Soil-Testing Outfit

It is desirable when out on a nature ramble to make soil tests in the field in addition to bringing soil back for detailed analysis. For this purpose some container is necessary; it

might consist of an old attaché case or a haversack or a wooden box with a carrying handle. Although the last is the heaviest of the three to carry, it has the advantage that the contents are not likely to be crushed. For the purpose of soil testing there should be a bottle of B.D.H. Universal indicator, a porcelain dish, a 100 ml. beaker, a bottle of distilled water, a funnel, a supply of filter paper, a capillator comparator and pieces of capillary tubing of the same diameter as the tubes in the comparator. It is not difficult to make your own comparator provided you have the same *proportions of indicator and water in the comparator as you* use for the soil test. You should also have a small bottle of dilute hydrochloric acid to test for calcium carbonate. The wooden case should be made with compartments so that these articles fit in compactly.

6. Ecological Apparatus

There are various kinds of ecological apparatus which can be made. For pond work, three types of net can be made. A plankton net (see fig. 7) can be made from fine silk, a

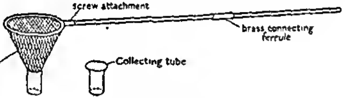

Fig. 7. Plankton Net.

wire ring, a cane and a supply of test tubes. If the mouths of the test tubes are given a wider lip by some simple glass-blowing it makes it easier to fit them in the silk net. A pond net (fig. 8) can be made from muslin, wire, and a cane. A drag net needs to be of strong construction, but can be made satisfactorily with strong coarse canvas or hessian, strong

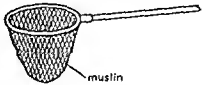

Fig. 8. Pond Net.

rigid wire and ropes (see fig. 9). There should also be a pond scoop consisting of a metal sieve at the end of a rod, and it should be possible to make this (see fig. 10).

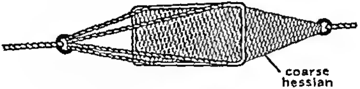

Fig. 9. Drag Net.

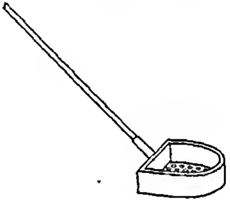

Fig. 10. Pond Scoop.

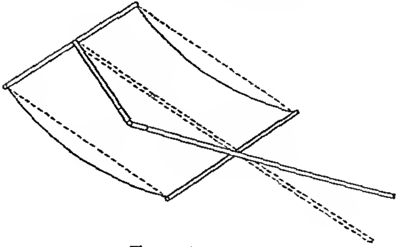

Fig. 11. Beating Tray

By means of a type of fishing line (see fig. 12) with a sinker, it is possible to measure the depths of a pond and thereby map the pond.

Other types of ecological apparatus which can be made include a beating tray, sweep-nets, butterfly nets, suckers, clinometers, measuring rods and lines, and light testers. Some information about the making of these can be found in books or pamphlets.[3] The beating tray should be such that one person can use it, holding it with one hand and beating with the other (see fig. 11).

Fig. 12.

Suckers can be made from 3 inch by 1 inch specimen tubes (see fig. 13).

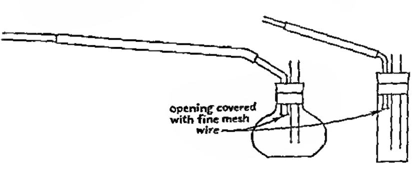

Fig. 13. Sucker.

7. Vivaria, Aquaria, etc.

Vivaria can be made quite easily; a useful design is illustrated in fig. 14. A good appearance in a piece of apparatus, even in a vivarium, should be aimed at. Of course, adequacy in fulfilling function is the main quality in a piece of apparatus. A vivarium should provide a good home for what it is intended shall be kept in it, be it lizards, frogs, toads, a grass snake, cockchafers, silkworms or stick-insects. It is desirable to have about six vivaria of different sizes because a grass snake would want a larger home than a cockchafer.

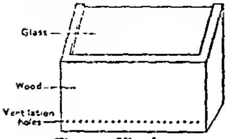

Fig. 14. Vivarium.

Aquaria are not so easily made because of the difficulty of making them waterproof. Unless either the science teacher or the laboratory assistant is an expert craftsman, I would suggest that it is better to buy aquaria. If they are bought, I recommend the angle-iron type because they are stronger. Not only that, but if one side becomes broken it can be replaced quite easily, but if an all glass aquarium is broken it is finished.

If an aquarium is made, it will be of the angle-iron type. It is essential that the glass plates meet along their edges and that waterproof cement is used. This can be obtained from laboratory furnishers.[2] For a sea-water aquarium it is absolutely essential that no salt water comes into contact with the metal since it readily corrodes the iron used in making the angle irons.

8. Auxanometers

Two types which have been made are illustrated in the drawings (figs. 15 and 16). One was entirely made from scrap materials including an old alarm clock found in a bin. To the minute hand axis of the clock is attached a circular plate

with two pegs 180 degrees apart. These move a smoked glass screen every half-hour and thereby cause the pointer (see fig 15) to make a mark. The pointer is attached to a lever which in turn is attached to the growing plant at the

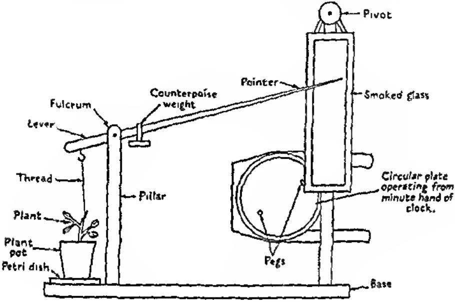

Fig. 15. Auxanometer.

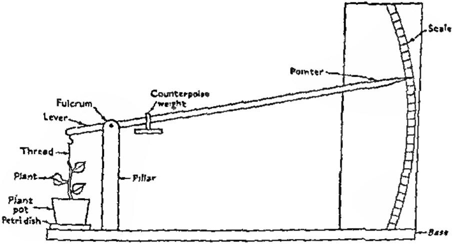

Fig. 16. Auxanometer.

opposite end. By measuring the difference between the marks it is possible to calculate the rate of growth of the plant.

The other type of auxanometer illustrated is simpler, but works quite well nevertheless. It largely depends on having a long lever with the fulcrum near to the plant end so that the amount of growth is magnified considerably in the recording.

C. Improvisation of Apparatus

The improvisation of apparatus is just as important as the making of apparatus. Basic pieces of apparatus can be assembled to make more elaborate apparatus, which is usually just as efficient as apparatus made up for the purpose and sold by laboratory furnishers.

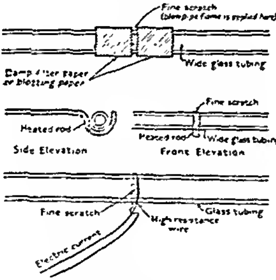

Fig. 17.

Apparatus can be fitted together to make equipment to demonstrate such experiments as convection, distillation under reduced pressure, manufacture of sulphuric acid, model gas works, electrical distribution, how water finds its own level and separation of the gases of the atmosphere.

To fit up apparatus of this kind requires mainly skill in

fitting and boring corks and I.R. stoppers and the bending of glass tubing. It is also useful to be able to cut glass tubing for making articles like a Force pump and a Suction Pump. This glass tubing can be cut with a file or better still a G. & T. glass knife.[4] Wider tubing is best cut by working a scratch round it with the glass knife and placing damp filter paper round on each side (see fig. 17). Then heat the shaped metal and hold the metal so that the curved part follows the line of the scratch; this should be sufficient to make a clean break. With thicker glass tubing the method can be modified by impinging a fine blow-pipe flame on the scratch or by wrapping a bare copper wire round the tubing in the position of the scratch and sending an electric current through it so that it becomes red hot.

It is also an advantage to be able to carry out not only simple soldering, but also silver soldering. For the former it will be found convenient to have a bobbin of solder with a core of fluxite and to use an electric soldering iron. More permanent joints between metals can be made by silver soldering. This requires a small forge which should be available in the metal-work room.

Ability to bore holes in glass with a china drill (see fig. 18) is also useful. This skill will be found useful in many ways.

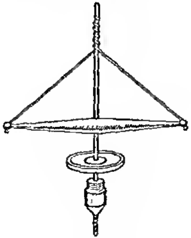

Fig. 18. China Drill.

For example, it may be necessary to bore a hole in the top part of a glass aquarium in order to make a tidal-sea water tank (see fig. 19).

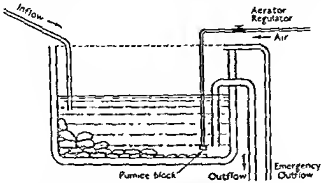

Fig. 19. Tidal Aquarium.

It may be desirable to make a thermostat for various experiments. Such a thermostat will be found particularly useful for maintaining cultures at the correct temperatures. The one illustrated in the drawing (fig. 20) was fitted up to

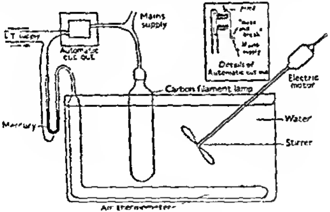

Fig. 20.

show the contraction of the muscle in a frog's leg when treated with extract of nettle leaves.[5] The muscle has to be kept at a special uniform temperature. A thermostat is expensive to buy, but can be fitted up comparatively cheaply from the following components: a large tank, electric motor

to operate stirrer, air thermometer, automatic cut-out and a good supply of glass tubing. A good deal of science can be taught in conjunction with the thermostat, e.g. applications of air expansion, electro-magnetism, electric currents and convection problems.

Relative density is often made far too academic in schools particularly when relative density bottles are used. These are unnecessary besides being rather expensive. An ordinary flask with a cork pierced by a fine hole will serve the same purpose. The volume of the flask does not often come into the calculation; the exact volume of the relative density bottle is the main reason why it is expensive. A good application of Relative Density and Archimedes' Principle is a quick method of finding the relative density of potatoes which I shall briefly describe.

A number of sodium chloride solutions are made up according to the following formulae:

TABLE I.

Relation between the concentration of a solution of common salt and its specific gravity at 20° C.

Per cent NaCl in the solution (w/w)	Concentration of NaCl (gm. per l. of solution)	Approximate weight of NaCl to be dissolved in 10 gals. of water		Specific gravity
		lb.	oz.	
8	84.5	8	11	1.0559
9	95.7	9	14½	1.0633
10	107.1	11	1¾	1.0707
11	118.6	12	6½	1.0782
12	130.3	13	9½	1.0857
13	142.1	14	14¾	1.0933
14	154.1	16	5	1.1009
15	166.3	17	11	1.1085
16	178.6	19	1½	1.1162
17	191.1	20	8	1.1240
18	203.7	22	0	1.1319
19	216.6	23	8	1.1398
20	229.6	25	0	1.1478

(Extract from W. G. Burton, *The Potato*, p. 286)

These are best kept in wide-mouthed jars; 2 lb. Kilner jars will do quite well. If the relative density of the particular solution is marked on the jar containing it, then the relative density of a potato can be determined quickly as follows:

Using wooden tongs or tongs made of perspex, find out in which solution the potato just sinks. The relative density of this solution is the relative density of the potato according to the Law of Archimedes.

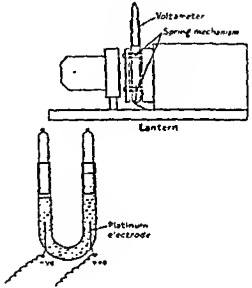

Fig. 21.

I will conclude this section by a few words about voltameters. Very often the voltameters supplied by laboratory furnishers are too small for a class of children to see. It is much better to make a voltameter which will go in the lantern in the place of the slide carrier. A U-tube could be used for this purpose having platinum plates attached to platinum wires which go through the sides of the glass at the base of the U-tube (fig. 21). When the electrolysis is taking place and the lantern is switched on, the children will be able to see a silhouette of the apparatus and the bubbles in the liquid. It will be necessary to use a supplementary lens in front of the lantern in order to give an upright image on the screen.

D. Repair of Apparatus

In order to repair apparatus, a teacher must cultivate certain skills. These are considered in chapter 6. The amount of repairing necessary will depend on how well the children are trained to handle apparatus and also on the care of the teacher himself in dealing with apparatus. It also depends on how the laboratory or science room is arranged; this is considered in the next chapter.

All apparatus requiring repair should be put in one special place and dealt with fairly soon. There is a tendency in some schools to put apparatus needing repair in the store room with the good intention of dealing with it, but it often becomes an intention only, which never materialises. Apparatus which cannot be repaired on the spot should either be sent away promptly for treatment or thrown away. Time should not be wasted in trying to repair things which are not worth it, as for instance endeavouring to seal the bulb of a flask when it has blown a small hole.

Repairs can in general be divided into simple ones and more elaborate ones. In the simple class there are such jobs as rewiring electric bell connections; rounding off the jagged ends of glass tubes that occur when pieces of apparatus with fitted glass tubes have these tubes snapped off; removing biological specimens from cracked containers when these contain liquid preserving fluids; cleaning the jets of Bunsen burners; and tightening terminals on various kinds of electrical instruments.

Repairs which come in the larger category are such kinds as those I shall enumerate.

Thermometers may have had their mercury columns divided. The columns can usually be joined either by shaking, placing the thermometer bulb in freezing mixture or heating it. Barometers may through ill treatment loose mercury. They have then to be refilled. This has to be done by filling the barometer tube with mercury and then inverting it into the reservoir without allowing air to enter. Such a technique requires some skill and it is usually found that the best way to do it is to place a small cork in the tube which is

not released until the barometer open end is below the mercury in the reservoir.

There is not space to give detailed instructions for treating all kinds of repairs likely to be required. I will mention the kinds of repairs likely to be needed. Voltmeters and ammeters sometimes need adjustment. The soldering iron is often useful in repairing connections in model wireless sets, in electric motors and dynamos. Sometimes transformers or coils need to be rewound. Condenser plates in rectifiers and wireless sets have to be straightened.

If either the science master or the laboratory assistant is skilled in glassblowing it should be possible to carry out repairs to broken glass-ware of the more expensive kinds such as Liebig condensers, distillation flasks, and still-heads. In all these cases it should always be considered whether it is worth while to spend time on carrying out the repairs. Usually it is not worth the time spent to try and repair serious breakages in any kind of glass apparatus.

Sometimes the glass coverslips of prepared slides get scratched by lowering the objective of the microscope so that it presses on the slide. This should not happen if pupils have been trained properly to use a microscope. To repair such a slide it is necessary to remove the broken cover slip, dissolve off the mounting agent and remount the specimen in fresh mounting agents. Unless the teacher can find out what the mounting agent is, he may discover that he is wasting his time. For example, if the mounting agent has been euparal, and he attempts to clear it with xylene he will produce an opalescent mess and in the process may lose the specimen.

Microscopes sometimes require attention. Substances such as Canada balsam get on the objective. These have to be removed carefully with xylene on a piece of cotton wool. Care should be taken to remove excess of xylene immediately so that it will not penetrate the interstices between the component lenses in the objective. At times the rack and pinion movement becomes stiff; when this happens the coarse adjustment should not be forced or the movement may be strained. This occurrence is sometimes caused by a hard

piece of grit getting in the teeth. The best procedure is to take the draw tube out and examine the rack and pinion mechanism. It may be necessary to straighten the cogs carefully with a strong steel instrument.

Sometimes burette taps become stuck and will not move. If they are kept greased with a suitable mixture they will not get in this state. Such a mixture is made by melting together equal parts of resin cerate and vaseline. However, if they do get stuck the best method I have found of loosening them is to dry the tap part thoroughly by gently heating in a Bunsen flame. When it has been allowed to cool pour some petrol in the burette and it will be found that as a rule it will penetrate the junction between the tap and the bore. Of course, if this happens the tap will be loosened. If this treatment will not put matters right the best thing to do is to remove the tap and jet by making a scratch with a glass knife just above the tap and briskly snapping it off. The broken end can then be smoothed off in the blowpipe flame and when the newly made jet is cool a rubber tube and clip can be attached and the burette is once more a serviceable instrument.

E. Maintenance of Apparatus

Apparatus always lasts longer if it is looked after well. Yet, how often is this the case in schools?

An elementary principle which is not regularly observed is that of putting apparatus away only when clean. This particularly applies to apparatus used in chemistry. If flasks, beakers, test-tubes and other apparatus cannot be cleaned immediately they should be put into a special place for apparatus needing to be cleaned. It is not so trivial to mention this as it may at first appear.

For the cleaning of glassware the most necessary items of equipment are swab cloths, tea towels, and draining pegs. The materials most useful are hot water and soap or some synthetic detergent like "Teepol"[6] or "Brylanz."[7] When the apparatus has been washed clean it should be left to drain and after the inside is dry, the outside only can be dried with a tea towel. Then the apparatus can be stored away.

When apparatus has to be cleaned and dried quickly, it is

best to put it in the hot-air oven after washing. This will quickly dry the apparatus.

Lenses and mirrors should only be cleaned by the teacher and then only lens cleaning tissue[3] should be used. After use it should be thrown away.

Metal work requires periodic care. Retort stands, tripods and other iron equipment should have an annual coating of aluminium paint, black stove enamel, or Brunswick black. If they are rusty, then the rust should be removed with emery paper before painting. It is a good plan to run over most metal in a laboratory with an oily rag once a week to prevent rusting. If brass-ware is corroded or tarnished it can be cleaned with a liquid consisting of concentrated hydrochloric acid containing as much oxalic acid as it will dissolve. The screws of clamps and other apparatus, Bunsen burner parts and gas taps require an occasional oiling, or greasing with tallow.

Sinks should always be kept scrupulously clean. This is not the job of the school caretaker; because he will not know how to remove dye stains (from microscope stains), for example. If sinks are always maintained in a clean condition stains are not likely to be difficult to remove.

When such stains do not disappear on the application of a scrubbing brush and hot soap and water, try various oxidising and reducing agents such as sulphur dioxide solution and hydrogen peroxide solution.

Crucibles are sometimes difficult to clean. If hot soap and water will not remove the material then it may be possible to burn out the substance with a hot flame. After that such corrosive liquids as technical hydrochloric acid and caustic soda solution may be tried. Use them first cold and then hot. These liquids may also be applied to residues in flasks and beakers.

Just one last point that is often overlooked. The glass stoppers and stop cocks of measuring glass-ware should be attached to the parent body by copper wire so that they do not get lost. Since taps and stoppers in this kind of apparatus are ground to fit, no other tap or stopper is likely to serve in the place of the original.

COMMON STOCK

For a laboratory to accommodate 25 children

Quantity Required	*Description of articles required*
50	Pyrex glass beakers, squat form with spout, 250 ml.
50	Pyrex glass beakers, squat form with spout, 500 ml.
50	Pyrex glass beakers, squat form with spout, 1000 ml.
50	Pyrex glass flasks, conical, 500 ml.
50	Pyrex glass flasks, flat bottomed, 500 ml.
50	Pyrex glass flasks, round bottomed, 500 ml.
10	Pyrex glass flasks, round bottomed, 1000 ml.
25	Glass filter funnels, plain, 15 cm. diam.
25	Glass filter funnels, plain, 10 cm. diam.
10	Glass funnels, for filling burettes, 5 cm. diam.
3 gross	Test-tubes, Unific, 6 ins. by $\frac{5}{8}$ in.
1 gross	Boiling tubes, Pyrex, 6 ins. by 1 in.
2 lb.	Glass tubing, 6 mm. ext. diam.
2 lb.	Glass tubing, 5 mm. ext. diam.
2 lb.	Glass tubing, 4 mm. ext. diam.
2 lb.	Glass tubing, 4 mm. ext. diam. capillary
3 lengths	Combustion glass tubing, 30 cm. by 20 mm.
3 lengths	Barometer glass tubing, 8 mm. ext. diam.
6	U-tubes, plain, 4 ins. by $\frac{3}{4}$ in.
35	Watch glasses, concave with ground edges, 7 cm. diam.
4	Calcium Chloride drying towers with tubulure at bottom, 12 in. by 2 in.
15 ft.	Rubber tubing, 4 mm. int. diam.
15 ft.	Rubber tubing, 5 mm. int. diam.
15 ft.	Rubber tubing, 6 mm. int. diam.
5 ft.	Rubber tubing, Pressure 5 mm. int. diam.
35	Bunsen burners, 13 mm., laboratory pattern
35 lengths	Tubing for Bunsen burners with special fitting 2 ft. long

Quantity required	*Description of articles required*
1	Batswing burner on cast iron base 8 in. high
1 gross	Corks to fit 500 ml. conical flasks
1 gross	Corks to fit 500 ml. flat bottomed flasks
1 gross	Corks to fit 500 ml. round bottomed flasks
1 gross	Corks to fit test-tubes, 6 in. by $\frac{3}{4}$ in.
1 gross	Corks to fit boiling tubes, 6 in. by 1 in.
1 gross	Corks, assorted, 1 in. to 3 in. diam.
1 gross	Corks, assorted, $\frac{1}{4}$ in. to 1 in. diam.
12	Rubber bungs to fit 500 ml. conical flasks
12	Rubber bungs to fit 500 ml. flat bot. flasks
12	Rubber bungs to fit 500 ml. round bot. flasks
12	Rubber bungs to fit boiling tubes, 6 in. by 1 in.
24	Assorted rubber bungs, one holed
24	Assorted rubber bungs, two holed
1	Glass tubing cutter (e.g. Griffin & George No. B23-697)
1	Set cork borers, $\frac{1}{8}$ in. to 1 in. diam.
1	Cork presser, malleable iron base, on wood board, ribbed wheel with eccentric motion
1 pair	Laboratory scissors, 6 in.
1	Hammer, Canterbury claw pattern, 8 oz.
2	Chisels, wood, Firmer (1, $\frac{1}{2}$ in.; 1, 1 in.)
6	Bradawls
1 pair	Cutting pliers, 6 in.
1	Tenon saw, 10 in.
1 pair	Pincers, 6 in.
1	Vice, engineers, $2\frac{1}{2}$ in. jaws
1	Electric soldering iron, light pattern, for 230 v. A.C.
1	Mercury tray, whitewood, 1 in. deep with hole and peg in corner
35	Triangular tripods, 5 in. sides, malleable iron top
35	Iron wire gauzes, 15 cm. square with circular asbestos centre
35	Pipeclay triangles, 6.5 cm. (for above tripods)
35	Sand baths, 15 cm. dia. tinned iron plate, shallow

Quantity required	*Description of articles required*
35	Test-tubes brushes
18	Test-tube racks, hardwood, 6 holes, 22 mm. diam. 6 pegs
2	Test-tube racks, hardwood, 18 holes, 22 mm. diam., 12 pegs
12	Wood blocks, assorted sizes for raising apparatus
4	Wooden burette stands, single
4	Funnel stands, wooden to take 2 funnels
1	Pestle and mortar, unglazed porcelain, 5½ in. diam., pestle fitted with wooden handle
1	Pestle and mortar, unglazed porcelain, 7 in. pestle fitted with wooden handle
1	Pestle and mortar, unglazed porcelain, 10 in. diam. pestle fitted with wooden handle
1	Pestle and mortar, iron 8 in.
35	Iron retort stands with bosses and clamps
12	Iron rings for above with boss heads, 2½ in. diam.
12	Iron rings for above with boss heads, 4½ in. diam.
12	Iron rings for above with boss heads, 6½ in. diam.
2	Thermos flasks, 1 pt. size
6	Porous pots 6 in. high for diffusion experiments
4	Boxes gummed labels, 9 by 4 cm. plain in 1000's

Physics Apparatus

For a laboratory to accommodate 25 children

18	Rectangular Glass Blocks, 10 by 4.5 by 2.5 cu. cms.
18	Prisms, 45° by 45° by 90°. Not optically worked
18	Drawing boards: laminated plywood with hard-wood edges, 16 in. by 23 in.
1 lb.	Pins, 46 mm.
18	Plane mirrors, 3 in. by 4 in. strips, unmounted
6	Convex mirrors, 50 mm. dia., various f.l.
6	Concave mirrors, 50 mm. dia., various f.l.
18	Bi-convex mirrors, 50 mm. dia., various f.l. from 5 cms. to 20 cms.

Quantity required	*Description of articles required*
6	Bi-concave mirrors, 50 mm. dia., various f.l. from 5 cms. to 20 cms.
18	Magnets, cobalt chrome, cylindrical 6 in. by $\frac{3}{8}$ in. dia.
18	Simple type compasses (needle fixed in 2 glass plates)
3 lb.	Iron filings, ordinary quality
18	Sifters for iron filings
1	Large compass needle, 10. cms. with agate axis on stand
1	Dip needle, metal stand to carry needle on rotating brass base graduated 0-90 four times, graduated arc 0-90 in single degrees with silvered scale, fitted to upright. Needle carefully balanced on steel axis
1 card ea.	Fuse wire, 5, 10, 15 amp.
6	Leclanché cells, 2 pt.
6	Copper plates, 10 by 5 sq. cms.
6	Zinc plates, 10 by 5 sq. cms.
1	Model lift pump, glass, mounted on hardwood board
1	Model Force pump, glass, mounted on hardwood board
2	Specific gravity bottles, light brown, 50 ml., adjusted with perforated stopper
1	Inclined plane with heavy metal base (e.g. Griffin & George, Microid A22-115)
3	Single pulleys, 15 cms. dia. in wrought iron
3	Double sheave pulleys, 15 cms. dia. in wrought iron
1	Treble sheave Pulley, 15 cms. dia. in wrought iron.
1	Wheel and axle compound, 15 cm. wheel, axle, 7.5 cms. and 3.8 cms. mounted on board
1	Weston differential pulley block tested to $\frac{1}{2}$ ton
3	Pendulum bobs, brass balls with screw eyes at top, $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{5}{8}$ in. diam.

Quantity required	*Description of articles required*
1	Compound bar, bars of copper and iron riveted, 20.4 cms. by 2.4 cms.
1	Ball and Ring apparatus, Gravesandes
1	Wood rod and Brass cylinder, with handle for conduction experiments
1	Ingenhousz apparatus to shew different conductivity of metals, 10 in. by 3 in. by $4\frac{1}{2}$ in. high
1	Davy Safety Lamp
3 pieces	Copper gauze, 12 in. by 12 in.
18	Thick metal calorimeters, iron, 4 in. by 2 in. by $\frac{1}{4}$ in. walls
18	Felt jackets to fit thick calorimeters
18	Copper calorimeters thin 4 in. by $2\frac{1}{2}$ in.
18	Wooden covers for thin calorimeters
1 each	100 grm. cylinders of Cu:Fe:Al:Sn:Brass:Pb.
1	Wet and dry bulb hygrometer, Mason's
1	Leslie's cube, 13 cms. diam.
1	Steam trap, glass, with corks
18	Measuring cylinders, 100 ml. on foot with spout
18	Measuring cylinders, 250 ml. on foot with spout
3	Measuring cylinders, 1000 ml. on foot with spout
18	Boxwood rulers, 1 metre, one edge ins. other cms.
6	Boxwood rulers, $\frac{1}{2}$ metre, one edge ins. other cms.
1	Chemical balance, 250 gm. sensitive to 1 mg. in case
18	Spring balances, 0-250 grms.
1	Compression balance with dial to read 20 kg. (or nearest)
1	Compression balance with dial, 14 lb. by 1 oz., 5 in. diam.
1	Box weights for chemical balance, 1 mg. to 50 grm. (Nivoc Grade III) or equal. *Nivoc specialities are made by Griffin & George*
1	Set weights, avoirdupois, iron ring pattern, $\frac{1}{2}$ lb. to 14 lb.

Quantity required	*Description of articles required*
1	Set weights, Metric, iron, ring pattern, 250 grms. to 5 Kgs.
18	Thermometers, Centigrade $-10°$ to $+110°$ engraved stem, enamelled back
18	Thermometers, Farenheit, $-10°$ to $+220°$ engraved stem, enamelled back
1	Max. and min. thermometer, Sixes, on metal scale with magnet
1	Aneroid barometer in brass case, 5 in. diam., open face to shew working
1	Syphon barometer, Mercury, mounted on wooden board with reflector
2	Boyles Law Tubes, 'J' tubes only
1	Apparatus to shew that pressure is transmitted equally in all directions, glass globe with equidistant holes and piston
2	Tin pressure cans, for atmospheric pressure experiments
1	Archimedes bucket and cylinder apparatus (for teacher's use)
1	Hydrometer, 0.700 to 1.000
1	Hydrometer, 1.000 to 1.500
1	Lactometer, simple type with paper scale
1	Electric bell, with 3 in. gong
1	Morse buzzer, No. 1, 3 ohms resistance
1	Key contact, Morse
5	Switch plugs, ebonite base, brass blocks, with terminals and contact plug, 3 ways
20	Flashlight bulbs, 2.5 v.
10	Car bulbs, 12 v. 24 w., bayonet fitting, 38 mm.
20	Holders for flashlight bulbs
10	Holders for car bulbs
20	Screw terminals, No. 3A, British S. Assn.
20	Spade terminals, insulated sleeves
	Stop clock, Smith's or similar type
	Roll solder with flux core
	Roll insulating tape, ½ in. wide

Chemistry Apparatus

For a laboratory to accommodate 25 children

Quantity required	*Description of articles required*
18	Thistle funnels, 25 cms. long
2	Circular pneumatic troughs, 14 in. diam. by 6 in. deep, stout glass
2	Circular pneumatic troughs, 16½ in. diam. by 7 in. deep, stone-ware
12	Cylindrical gas jars with heavy foot and ground flange, 30 by 7.5 cms.
12	Covers for gas jars, glass, circular, ground one side, 6.5 cms.
18	Pipettes, Students, 25 ml.
5	Pipettes, Students, 10 ml.
3	Pipettes, Students, 5 ml.
2	Pipettes, Students, 1 ml.
2	Burettes, students type, 50 ml., fitted with pinch-cock and reading to $\frac{1}{10}$ ml.
18	Porcelain basins, 127 mm. diam., cap. 375 ml.
2	Bell jars, stoppered, 30 cms. high, ground base, with plates
2	Bell jars, with tubulure at top, 30 cms. high, ground base with plates and solid rubber stoppers
1	Aspirator, 3 litre capacity, with tubulure at bottom, clear stout glass
2	Leibig condensers, 50 cms. long, inner tube cupped at one end, and drawn out at other
2	Dessicators, Scheiblers, accurately ground top and rim, flat bottom with perforated zinc stage, 8 in. diam. inside
2	Stoppered Retorts "Pyrex" glass 250 ml. cap
1	Water Voltameter, funnel type with nickel electrodes (Allen & Moore)
10	Porcelain Crucibles and lids Sillax, No. 0, 19 ml.
4	Beehive Shelves, earthenware, 12 cms. diam.
2	Earthenware troughs, 12 in. diam. by 5 in. deep

Quantity required	*Description of articles required*
6	Combustion boats in glazed porcelain, Sillax, $3\frac{1}{4}$ in. by $\frac{1}{2}$ in. by $\frac{3}{8}$ in. deep, one end rounded, other square
2	Water baths, students, enamelled steel, 6 in. diam. 4 in. high, fitted with 6 copper rings
3	Woulff's bottles with 2 welted necks, 500 ml. capacity
2	Brass Deflagrating spoons with caps
18 prs.	Crucible tongs
3	Spatulas, composition, 12 cm. long
6 pkts.	Wood splints
6 books	Litmus paper, Red
6 books	Litmus paper, Blue
2 boxes	Filter paper, 32 cms. diam. (Griffin & George 100 or equal)
2 boxes	Filter paper, 18·5 cms. diam. (Griffin & George 100 or equal)
12	Asbestos mats, 20 cms. by 20 cms.
1	Letter balance to weigh up to 50 grms.
1	Filter pump, metal for fixing to tap, Model for $\frac{1}{4}$ in. pressure tubing and $\frac{1}{4}$ in. B.S. pipe
3 ft.	India rubber pressure tubing to fit above filter pump
1	Still for distilling water (e.g. Manesty) for fixing to wall
18	Blow pipes, mouth, N/P Brass, with bone mouth-piece
	Reagent bottles, 8 oz., with sand blasted labels
	Reagent bottles, 16 oz., with sand blasted labels. Conc. H_2SO_4
	Reagent bottles, 16 oz., with sand blasted labels. Conc. HCL
	Reagent bottles, 16 oz., with sand blasted labels. Conc. HNO_3
3	Porcelain plates for reagent bottles with rim
2 books	Labels, varnished and gummed with 360 names and formulae

Quantity required	*Description of articles required*
24	Winchester bottles, narrow necked, 3000 ml.
80	Reagent bottles, 8 oz. size, plain, narrow mouthed
20	Reagent bottles, 8 oz. size, plain, wide mouthed
1	Buchner funnel, 6 in. diam.
1	Filter flask for Buchner funnel, with bored rubber bung

BIOLOGY APPARATUS

For a laboratory to accommodate 25 children.

Quantity required	*Description of articles required*
1	Klinostat, small size
1	Auxanometer
1	Microprojector
1	Microscope (with 8X and 10X eyepieces and 1 in. $\frac{2}{3}$ in. and $\frac{1}{6}$ in. objectives)
1 gross	Microscope slides 3 in. by 1 in. extra white
$\frac{1}{2}$ oz.	Microscope cover slips No. 2, $\frac{1}{150}$ in. thick, $\frac{3}{4}$ in. diam.
18	Tripod magnifiers 4 cm. bi-convex lens with adjustment
1 set	Dissecting instruments comprising: 1 No. 1: 1 No. 8: 1 No. 12: 1 No. 14 scalpels: 1 pr. forceps 5 in. straight: 1 pr. forceps 5 in. curved: 1 pr. 5 in. scissors straight: 1 pr. 5 in. curved scissors: 2 needles: 1 section lifter, 1 razor in case
50	Needles mounted in wooden handles
12 prs.	N/P Forceps, blunt ends, 5 in. straight
5	Collecting boxes, pocket size, to hold 5 corked tubes
1	Vasculum, japanned, with loops for shoulder straps, complete with webbing straps, 21 ins. by 10 in. by $5\frac{1}{2}$ in.
1	Aquarium, angle iron, complete with glass, 18 in. by 12 in. by 12 in.

Quantity required	*Description of articles required*
1	Aquarium, angle iron, complete with glass, 24 in. by 12 in. by 12 in.
1	Aquarium, angle iron, complete with glass, 30 in. by 15 in. by 15 in.
1	Aquarium, angle iron, complete with glass, 36 in. by 18 in. by 18 in.
1	Electric aerator for aquarium
1	Plankton net for pond dipping, complete with set of 3 sticks
1	Pond scoop complete with set of 3 sticks
1	Butterfly net, Kite net frame, Ring 11 in. diam., white mosquito net
1 pr.	Perspex aquarium forceps
1	Microscopic slide box for 100 slides, 3 in. by 1 in., grooved
1	Dissecting board, 22 in. by 15 in.
50	Assorted specimen tubes and bottles
12	Kilner jars, 2 lb. size
4	Setting boards (1 each 1 in, 2 in., 3 in., 4 in. long)
2 boxes	Entomological Pins, No. 8
2	Relaxing tins, zinc, 7 in. by 4 in. by 2 in., corked at bottom
4	Storage boxes for insects, 13 in. by 9 in.

Summary

A. What should a school requisition?

B. Making of apparatus.

1. Microprojector.
2. Wheatstone Bridge.
3. Potentiometer.
4. Light Ray Apparatus.
5. Soil-Testing Outfit.
6. Ecological Apparatus.
7. Vivaria, Aquaria, etc.
8. Auxanometers.

C. Improvisation of Apparatus.

D. Repair of Apparatus.

E. Maintenance of Apparatus.

REFERENCES (CHAPTER SEVEN)

[1] See *The Teaching of Science in Secondary Schools* (John Murray), page 118. Reference to explosion occurring with impure mixture of potassium chlorate and manganese dioxide.

Also Board of Education Administrative Memo. No. 167.

[2] See *Instructions for Collectors: Insects.* (British Museum: Natural History.) 1s. 6d.

Also pamphlets of the Amateur Entomologists' Society.

[3] L. Walden, *Laboratory Cements and Waxes* (Modern Science Memoirs; John Murray).

[4] G. & T. Glass knife obtainable from Griffin & George Ltd.

[5] Experiments on nettle stings (effect on muscles), see *Discovery*, April, 1948, IX, *4*, *102*, *103*.

Also N. Emmelin & W. Feldberg, *Journal of Physiology*, 1947, *106*, 440.

[6] "Teepol" obtainable from Shell Chemicals Ltd.

[7] "Brylanz" obtainable from George T. Gurr, 136 New King's Road, Fulham, London, S.W.6.

[8] Lens cleaning tissue obtainable from Flatters and Garnett Ltd.

CHAPTER EIGHT

THE RELATIONSHIP BETWEEN GENERAL SCIENCE AND APPLIED SCIENCE

The only applied Sciences taken in Secondary Modern Schools are Rural Science and Domestic Science so I will concentrate my attention upon these. At the end of the chapter, I will briefly consider the impact of pure science upon vocations which have applied science as inherent parts such as engineering, building science, bakery, chemical engineering and pharmacy.

A. General Science and Rural Science

1. School Garden; Livestock and Laboratory

It is essential in a school that the Rural Science should be based on pure science. There is no place in education for the school garden whose only purpose is the production of vegetables for the school canteen. The purpose of the school garden should always be educational whether it be for instruction in Rural Science; a source of supply of specimens for the Science lesson or the site of outdoor lessons in the subject during good weather.

School Rural Science should involve not only the garden but also livestock and some practical work on actual farms. I wish to deal with a number of matters relating to these broad divisions of the subject.

The vast amount of scientific material to be found in the gardens and amongst the livestock cannot be overstressed. In the garden there is a source of plants of many different families. There are also weeds; diseases to be investigated and insect pests to be studied. There are numerous other animals such as woodlice, spiders, birds and small mammals to be observed. Soil is another source of material for not only can the soil be analysed, but also it is often true that there are different kinds of soil in different parts of the school garden.

The livestock offer sources of a different kind. There may be rabbits, pigs, poultry, bees and goats. Also there are the pests and diseases of these to consider.

2. Horticulture

Gardening today is much more scientific than it was twenty-five years ago. Soil can be analysed and as a result of the analysis, the necessary treatment can be decided. The acidity of the soil can be measured with great accuracy.

Artificial manures can be applied with scientific skill. Under laboratory conditions we can grow plants under different circumstances with different elements eliminated in turn from the nutrient medium in order to observe effects. At Long Ashton Research Station[1] plants are grown in sand to which solutions of known composition are added. This Station is trying experiments on the effects of such elements as boron, iron, aluminium and molybdenum. The work is revealing some interesting results.

Germination can be studied both under garden conditions and in the laboratory. Studies in germination should go beyond traditional experiments with peas and beans. For example, the viability of seeds can be tested by having certain numbers on moist blotting paper in a Petri dish and noting the percentage germination. When this is tried with different seeds, the accuracy of the figures on the seed packets can be verified.

The various methods of propagation employed in the garden, such as division, layering, propagation from leaves, grafting and budding can be considered scientifically. The part the cambium layer plays in most of these methods should be dealt with fully.

The control of pests and diseases may also have its counterpart in the laboratory. Life histories of such pests as the click beetle, cabbage root fly, blackcurrant mite, crane fly and earth louse should be studied. Diseases are probably more difficult to study, because they involve a good deal of microscope work of rather high quality.

Examples for the elaborate subject of plant structure can be obtained from the garden. Not only should we be able to

find monocotyledons and dicotyledons but also conifers, mosses, ferns, lichens, fungi, and algae. Varieties of the different parts of plants can be found. Flowers of all types can be got from the garden such as actinomorphic, zygomorphic and asymmetrical. The relation between these and pollination can be studied in detail. Then there are different types of leaves of different shapes and sizes and textures.

The garden provides an excellent opportunity for the study of weeds. Why do some weeds grow in some places and some in other places? What is the best way of keeping down weeds?

3. Forestry

It seems to me that it would be good if schools, where possible, developed a small forestry estate. Trees are the noblest of garden plants which when grown properly might be said even to possess character. Excellent advice is given in books produced by the Forestry Commission.[1] The school plantation should contain trees of as many different kinds as possible both deciduous and evergreen; timber producers and ornamental trees. There should be a nursery where young trees are propagated and developed.

Trees have pests and diseases peculiar to them. Dead trees, which even the school forestry estate will have from time to time, are favourite homes for beetles. The type of beetle inhabiting a tree seems to vary with the stage of decay. Beetle attack often follows fungal diseases, though fungal disease can arise through penetration because of a defect caused by other insects such as green flies and caterpillars.

4. Livestock

The school livestock presents a splendid set of types for comparative anatomy and physiology. On the one hand there is that highly placed social insect, the honey bee and on the other we have those interesting vertebrate types: the hen, the rabbit, the goat and the pig. Of course, it is always desirable to study the mode of life of an animal before considering its structure and the functions of its organs. In considering these domestic types it is desirable to compare

them with their near relatives which are wild and, if possible, known to the children. The honey bee can be compared with the bumble bee and the solitary bee. The hen can be compared with the wood pigeon. The rabbit can be compared with its wild counterpart and also other rodents. With the goat comparison is not so simple; we should have to take the children to the zoo o see similar wild types. The same remark would apply to the pig.

The scientific reasons for care in looking after livestock might also receive attention. Judging by the bad way in which domestic animals are often kept, it is evident that many people pay little regard to this matter. This must be due either to ignorance or laziness.

Any animal that lives under our care should have good conditions. Surely the zest for life cannot be denied our livestock. We may eventually kill them for food, but whilst they live they ought to live well. This is desirable not only from the point of view of the animal, but also because a good living animal gives a better food yield and also since the keeping of livestock in school is an educational matter, we must not neglect the important educational principles involved in the care of livestock.

The care of livestock should include good housing, cleanliness of living quarters and of dishes for food and water, and well-prepared and adequate food. There should also be a sufficiency of fresh air without undue draughts, and with adequate natural lighting.

Good housing means not only well-made huts, but also that the huts are big enough. There should also be consideration given to the sociability of animals. Some animals simply do not like to be alone; they should have companions. This remark applies to all domestic animals mentioned though there will have to be considerations regarding incompatibility, such as the undesirability of keeping two adult buck rabbits together. Where there is the danger of animals fighting, the mere sight of each other is usually enough social contact.

Cleanliness of living quarters is important, because not only is it pleasant living in clean surroundings, but also

cleanliness keeps down pests. The scientific principles behind this cleanliness should be made clear. When pests are found, they in themselves will provide good materials for lessons. Such pests as the acarine mite of the bee and red-spider and the louse of the hen are most interesting subjects.

The feeding of animals is as important as the feeding of human beings in many ways. They can no more do without carbohydrates, fats, proteins and mineral salts than we can, though it may be desirable to have different proportions of these foods. They must also have vitamins, but not necessarily the same ones that we have. This matter requires a good deal of investigation.

5. Garden Pond

The garden pond offers much scope for science teaching. It is desirable that the pupils should make their own garden pond in a correct way. They should choose a good site and excavate to the desired depth. The floor should be cemented and should contain a drainage hole fitted to a pipe leading to a drain. The walls should be made by filling the space between the shuttering with cement and broken stone. A double wall with clay in the intervening space is best. The whole of this brings in much science. There is the mechanics of erecting shuttering to support such a load of cement and stones. Then the hydraulics of the water-filled pond can be carefully considered. The increased tensile strength of reinforced concrete over ordinary concrete might be measured in the laboratory.

When the pond is filled with water and then set up as a balanced life unit, we have a most elaborate set of materials for scientific study. There are the seasonal changes to consider, particularly in the Spring and Autumn, when, owing to the maximum density of water occurring at 4° C., there are convection changes at these times which interchange the top and bottom layers of a pond.

By having an artificial marsh and setting up plants to show the gradual change in type from xerophytes to hydrophytes like lemna (which even has its roots floating) we have most useful material for the teaching of science.

Consideration of the animal life brings in a host of problems. There is the diversity of animal types which includes members of such phyla as protozoa, coelenterata, platyhelminthes, annelida, nematoda, arthropoda and mollusca in the invertebrate category and amphibia and pisces in the vertebrate category. There are problems of surface tension which obviously play a large part in the lives of plankton plants and animals and in those intriguing surface dwellers like notonecta, gerris and the water scorpion.[8]

There are also the problems concerned with what is called in a rather picturesque way, "the Web of Life". Children should study changes in the population of a garden pond. It will change from time to time. The plants supply the ultimate food of the animal population. The animals can be divided into predators and prey. Obviously if the food supply of the predators runs out, there will soon be no predators.

The garden pond can be compared with natural fresh waters such as streams, rivers, dew ponds, ponds and lakes. They are all different and present different aspects of the problems of freshwater life.

6. The Greenhouse

The pond tends to be a restricted community apart from what can enter into the pond or alternately leave. This entrance and exit may be affected by walking or flying.

The greenhouse also tends to be largely a closed community apart from what gets in through the open windows or the door and what is brought in with the soil, the plants or the human entrants.

The greenhouse differs fundamentally from the pond in that it is usually established for the purpose of raising seedlings, growing special flowers such as chrysanthemums, primulas and cinerarias, growing early lettuce and growing tomatoes and cucumber.

It would be useful if schools could have at least two greenhouses, one for the purpose just mentioned and the other for the purpose of scientific experiment. Scientific experiment might for example include culture in plant pots using sand for such plants as sugar beet and potatoes with definite con-

trolled mineral deficiencies. We can get a power of control in the greenhouse which is not possible outside in the garden. But we must not delude ourselves with supposing that our control is perfect. Insects can get in through the ventilators and fungoid spores can also get in this way.

Where insect pests do get into the greenhouse, we may have excellent opportunity to show methods of biological control by the introduction of a predator. If we are unfortunate enough to have an attack of white fly we should introduce *Encarsia formosa* (a chalcid wasp). This method of control, which is now being used on quite a large scale, will possibly supersede the spraying methods in due course Where applicable, it is found to be more thorough, because the predator has searching powers not found in droplets of spray. It has also the tremendous recommendation of cheapness in comparison with the chemical methods.

In connection with the greenhouse, we must not forget the practical application of the use of the maximum and minimum thermometer and of light intensity. The heated greenhouse also presents scientific problems concerned with fuel and convection.

7. The Farm

The farm brings in many of the scientific principles already considered in relation to the school garden and livestock but it also introduces other scientific problems.

Crops grown on farms are produced on a much bigger scale than the school garden crops and they often differ in kind.

The cultivation of a field of ten acres is a very different proposition from a school garden of one acre. What is more, such a field may be planted with one crop. If the farming is to be economical, as indeed it must, then the ploughing, sowing, tillage and harvesting must be accomplished in the shortest possible time by the most efficient means available. Where possible machinery should replace manual labour because it is not only cheaper, but quicker. All this involves scientific planning of quite a high order.

This also introduces the subject of the farm implements. These are all based on well tried and often ancient mech-

anical devices such as the lever, and its derivatives: the screw and the wheel. Power driven machines like the tractor and combine harvester also bring in the internal combustion engine. In a school course it is interesting to consider the history of farm implements for it is a very fascinating subject.

The treatment of pests and diseases has to be done on a large scale. This involves elaborate spraying machines of various kinds according to the area to be covered and the accessibility of the crops. Spray nozzles provide a topic in themselves. These are very carefully designed in order to wet surfaces adequately.

The farms in the vicinity of a school may go in mostly for fruit cultivation such as apples. This special type of cultivation should be considered from its scientific angle. There may be special crops such as asparagus, rhubarb or early tomatoes. These all bring their peculiar problems.[4] The growing of rhubarb in the dark to get an early crop involves a phototropic principle. It is a very strange sight to see about an acre of rhubarb growing in a dark shed only illuminated by electric light for cultivation and harvesting.

A farm may be largely concerned with milk production, or stock-raising or egg production. These types of farming bring in considerations of animal breeding. The best milk, the best meat and the finest eggs are obtained from carefully bred and selected animals. There is probably no better way of introducing the subject of genetics than through the kind of animal breeding necessary for good farming.

Animal pests and diseases should also receive consideration. These are usually very interesting for they have usually quite intriguing life histories. The warble fly[5] for example, begins its life as an egg on the hair of a cow's leg. When the grub hatches out it crawls into the flesh upwards to the gullet of the cow. No one appears to have discovered why the grub finds its way to the gullet. It may be to obtain a store of air; after all, certain beetles and water spiders come to the surface of a pond to collect air bubbles which are used in respiration. from the gullet the grub migrates to the back of the cow where it pupates. The pupa wriggles out through the skin of the cow and falls to the ground. In due course the adult

stage is reached. The adult flies mate and then the females go along and lay eggs on the hairs of cows' legs and so the insect carries on. This is but one example of the pests.

Finally in connection with the farm there is the question of milk production.[a] The question of pure and good quality milk has been brought to our notice very much of late, particularly in connection with milk for children. There are still farmers selling milk who do not appear to understand what is meant by pure milk. It is desirable that not only farmers, but also the general public should understand the scientific principles underlying milk production. It begins with the maintenance of good pedigree herds of cattle. These are kept under good conditions including sound housing and a correctly balanced diet.

Modern milking is usually carried out electrically and records are made of yields. Very often the milk goes from the farm in containers to be pasteurised or sterilised at a centre. The different treatments should be made clear to the children. It is also desirable to explain the difference between pasteurised and sterilised milk. Cleanliness at all stages of the procedure is an important factor.

B. General Science and Domestic Science

Let us consider the relationship under four headings, viz.

Nutrition and Food Preparation.
Laundry Work.
Cleaning.
General Home Management.

1. Nutrition and Food Preparation

It is still true to say that food is often spoiled in its preparation. Although Domestic Science is primarily concerned with food preparation, there should be certain well-defined scientific principles considered.

In general, raw food has higher food values than cooked food. The question then arises: why cook it? In the case of such foods as cheese, tomatoes, strawberries and apples this question might well be asked seriously. From a nutritional

point of view there are only two good reasons for cooking food: (1) to destroy spores of fungi, eggs of parasites and minute animals that do occur on some raw foods such as pork, most fish, mushrooms and cabbage; (2) to make the food more readily digestible, e.g. by breaking down the cell walls of rather hard vegetables, such as potatoes, parsnips and artichokes, and by breaking up the tough tissue of certain kinds of flesh such as steak. There are, of course, in addition certain psychological reasons for cooking food, but these do not concern us here.

Consideration of the principles of nutrition is pure science. An understanding of carbohydrates, fats, proteins, mineral salts and vitamins is desirable on the part of all adults. The subject is too involved for more than a superficial knowledge to be expected. But the study should not stop here.

There is the question as to what happens to food and drink when it enters the body. A knowledge of digestion and assimilation is desirable. The matter of the effect of enzymes is becoming of increasing importance in our knowledge of nutrition. Thought should also be given to elimination which is essential to the well-being of man.

2. Laundry Work

The importance of changing and washing undergarments cannot be overstressed. There should be some knowledge of the different properties of cotton, wool, silk, artificial silk, linen and nylon so far as human wear is concerned. Their various degrees of insulation should be considered. The degree of sweat absorption is an important matter.

The body can only continue to perspire freely if there is free access of air through the clothes worn. Now if the underclothes are made of wool and the air interstices become clogged with sweat, the body can no longer carry on sweating naturally, and injury is likely to result.

There are other reasons why undergarments should be washed frequently. Rancid sweat in wool forms a good medium for the growth of bacteria which can be very injurious. Then again, it is surely nonsensical to have a bath and then put on dirty underclothes.

Laundrywork also concerns night apparel, handkerchiefs, table linen, sheets and blankets. These are washed for very similar reasons, though, of course, sweating is not likely to be a factor causing dirty table linen.

3. Cleaning

There are other kinds of cleaning besides laundrywork. Windows, furniture, taps, fireplaces, baths, wash-basins and W.C.s are to be kept clean. Clean windows are desirable not only to improve the view, but also to let more sunlight and to keep down bacteria and larger pests. In fact much of the cleaning of these articles mentioned is specially necessary to prevent the growth of bacteria and multiplication of undesirable plants and animals. There are other factors, for example, the fire is not likely to be easy to light if the fireplace is clogged with clinkers; also there is the aesthetic factor, particularly in regard to the bathroom. There is no room that looks better than a well-fitted and meticulously clean bathroom; on the other hand no room looks worse than a dirty and untidy bathroom.

4. General Home Management

A well-designed home is based on sound scientific principles whether the designer is aware of it or not. Labour-saving devices carefully arranged make for efficiency and reduce fatigue. Careful planning in housekeeping has a good deal of scientific method behind it. Harmonious colour schemes follow optical laws even though the housewife is unaware of them. Planning work so that drudgery is eliminated is a scientific problem.

Then there are scientific principles involved in painting, staining, pointing and even in the lubrication of door hinges.

The household tasks which specially involve scientific knowledge such as repairing a fuse, mending an electric iron, maintaining a vacuum cleaner in good order, fitting a washer to the tap, easing the main gas tap, cleaning the gas stove and fixing a new electric-lamp-fitting are tasks which every housewife should be able to carry out.

5. Mothercraft

In many of the enlightened schools, the girls are given instruction in mothercraft for they will be the mothers of the future. The argument that 14-15 is too young for this is untenable since most girls are not likely to get preliminary training later in life. The real experience often occurs quite soon after they leave school.

Whilst mothercraft is linked with sex, it is a very different subject. Although an infant is the infant of both his father and mother, the early years are very much the concern of the mother, particularly in most homes which secondary modern boys and girls will eventually form. It is not right that girls should in later life enter into motherhood with no scientific knowledge of what it means. The decline of the population of this country is probably due in no small degree to wrong ideas of mothercraft, besides economic factors.

Girls should know something about how the embryo child is originated and developed in the womb. They should also know how it is born. Mothercraft begins as soon as a woman knows she is bearing a child. She should, if she is to be fair both to herself and her future child, take adequate nourishment and take suitable exercise. Pregnancy should not be regarded as an unhappy state.

After the child is born, the mother should understand the methods of catering for the developing child, his feeding, sleeping, elimination habits, exercise, posture and clothing. It is surprising how many people are woefully ignorant of these matters. All these are based on science. To take one example, that of feeding. Today some women consider it old fashioned to feed their own babies in the way nature intended. It is common sense that the normal mother produces a much more suitable food in her own breast than that obtained from a tin. Milk obtained from tins is prepared from cow's milk which is the food for a calf, but not correct for a baby. It is true that some brands of baby food consist of dried cows' milk plus such substances as lactose in an effort to approximate to human milk, but they cannot be quite the same. Then again consider the trouble required when powdered milk is used: the measuring and the sterilizing take quite a time.

C. Other Applied Sciences

The other applied sciences are truly vocational such as engineering, building and mining. These have been considered earlier in this book.

It is always important that the true relations between pure and applied sciences should always be maintained. Applied science is primarily carried out to serve man but it must follow the same laws as pure science, it cannot do otherwise.

Summary

A. General Science and Rural Science.
1. School Garden; Livestock and Laboratory.
2. Horticulture.
3. Forestry.
4. Livestock.
5. Garden Pond.
6. Greenhouse.
7. The Farm.

B. General Science and Domestic Science.
1. Nutrition and Food Preparation.
2. Laundry Work.
3. Cleaning.
4. General Home Management.
5. Mothercraft.

C. Other Applied Sciences.

References (Chapter Eight)

[1] Long Ashton Research Station; Annual Reports (Bristol University).

[2] Books produced by the Forestry Commission.

[3] Mellanby, *Animal Life in Fresh Water.*

[4] See publications of the Ministry of Agriculture and Fisheries.

[5] Warble Fly Literature: Consult Hide & Allied Trades Improvement Society, 75 Burdon Lane, Cheam, Surrey.
Also:
Styles, F. W. (1924), *British Medical Journal*, 1, 1086.
Warburton, C. (1922), *Parasitology*, 14, 322.
Veterinary Record, Feb. 17, 1945.
1942, Journal of Irish Department of Agriculture.

[6] See Silent Film on "Milk Supply": Ministry of Education, part of Visual Unit on Local Studies.

CHAPTER NINE

CORRELATION BETWEEN SCIENCE AND OTHER SCHOOL SUBJECTS

A. Science and Mathematics

The fact that science at its best is quantitative, means that really to understand science requires a good knowledge of mathematics. Even in the Secondary Modern School, it is a mistake to give a science course bereft of quantitative work. It is an essential part of scientific training to insist on accuracy and this must by its very nature bring in mathematics.

In some schools the science scheme includes the measuring of the volumes of spheres, cylinders, and cones and the weighing of pieces of wood and lead and this work is simply done for the purpose of measuring. This kind of thing is mathematics and should be done in the mathematics lessons. Scientific experiment makes use of mathematics as one of its tools, but mathematics never becomes science.

There are ample opportunities to utilise mathematics in the science course. Let me mention a few.

Children should learn something about graphs in the mathematics lessons. Graphs and co-ordinate geometry are very useful mathematical forms to the scientist. Co-ordinate geometry is very much more appealing and useful than arithmetic of stocks and shares. I have reproduced here some graphs in connection with some research I have been doing on Vitamin C in potatoes. In the first diagram (fig. 22) there are various graphs showing the depreciation of Vitamin C during storage. Notice that although these are drawn as continuous lines, they are in fact based on the points shown. The co-ordinates of these particular points are the results of careful experimental work. But the points presupposed on the lines joining these fixed points are really the result of interpolation. Now this is a different kind of graph from the one representing $y=x^2$, where every point in a carefully drawn graph is reasonably accurate.

Also in this diagram you will see a shaded portion which really is a composite graph, a superficial graph if you like, giving the general consensus of opinion. This is a useful device.

In the second diagram (fig. 23) a method is shown of representing three dimensions. Two dimensions are represented by the axes (Vitamin C content on the *Y axis* and *length of time in days on the X axis*) and *the third dimension* (percentage humidity) by the particular graph. This arrangement tells us something about the storage conditions of potatoes not easily found any other way. We see that an artificial storage condition with a humidity of 88 per cent is comparable with clamp conditions, where in fact the mean humidity was found to be the same for the same fall in Vitamin C content under artificial conditions.

Sometimes an adjustment of the scales along the axes will elucidate a problem not seen with certain scales. To the scientist the graph is a very useful tool.

Measurement with all kinds of instruments, from the simple ruler to such complicated instruments as the *p*H meter, the Lovibond Tintometer and the spectrograph, is used in science. The measurement is used to elucidate problems and is not an end in itself. An important factor in the use of measuring instruments is their degree of accuracy. It should be part of the teaching of mathematics to indicate what is meant by probable error and what it is likely to amount to in a particular case. In general, error of measurement arises from two weaknesses: (1) the relative inaccuracy of the instrument and (2) the varying ability of the observer. You can often discover what the margin of error is in a particular instrument, but the subjective error of the observer cannot always be accurately estimated. As a corollary to this, we must refrain from reading into results conclusions which are not justified on the evidence. This is where the validity of the results comes in. We must know how far our conclusions are based on fact.

Calculus is used in a number of scientific measurements. This subject is, in its elementary stages, easier than many kinds of arithmetic. It is possible that "A" children in the last

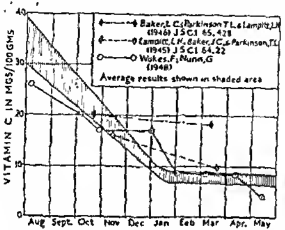

Fig. 22. Seasonal variation in Vitamin C content of potatoes stored in clamp.

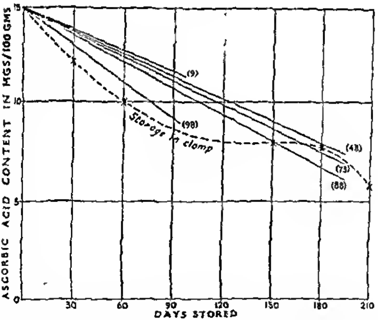

Fig. 23. Fall in the Vitamin C content of potatoes under different storage conditions. Nos. in brackets give humidities in % for artificial storage conditions.

year in a secondary modern school may be able to attempt it. A knowledge of this subject opens the way to a most fascinating study. Exercises in mechanics involving velocities and accelerations are much more easily carried out by means of the calculus. It is also useful in the analysis of graphs involving gradients and areas under the graphs.

A good deal of geometry comes into a subject like ecology. In particular do we use it in surveying the terrain. Contours are entered on our maps after using a theodolite for finding heights of points along well-defined lines in a well-arranged geometrical pattern built up from an accurate base line. If the base line can be estimated in regard to a bench mark on the ordnance survey map so much the better for the accuracy of our work. In ecology we also get the mapping out of quadrats, the measurement of the soil depths, estimating the girths and heights of trees, obtaining the submarine contours of ponds, and measuring light intensities. All these are examples of applied mathematics.

There is also a place for the application of statistical mathematics to our scientific problems. Some of this might well be done in schools. All children should know what a mean value is and it is desirable for the brighter children that they should know what is meant by the standard deviation of the mean.

It should be possible to show that the statistical method is particularly valuable in biology when we are comparing living things. A gross of drawing pins in a box are almost identical, but a gross of peas in a packet are all different. When we speak of a drawing pin in a box we speak of each one, but when we speak of the peas we must refer to the average pea because they are all different.

This variation of living things brings in not only such matters as the mean or the average, but it also brings in the matter of sampling. Supposing you are estimating the number of oak leaves in a wood damaged by pest or disease. You must not just count ten from one branch and base your estimate on that; such would not be a fair sample. Leaves at the tops of trees may be attacked more than those near the ground; trees on the periphery of the wood may be attacked

more than those in the centre. Trees near ponds may be attacked more than those in comparatively dry parts.

Finally in the mathematics lessons there is often a place for the solving of scientific problems. It is surely better if the problems solved in mathematics are real problems rather than invented ones. Children always prefer real work. Reducing the volume of a gas produced in the laboratory to N.T.P. is a good exercise in the multiplication of fractions.

B. Science and Handicrafts

Whilst improvisation is not always desirable in a school, it has certain advantages.

The amount of money available for the purchase of apparatus and chemicals for a particular school has a limit, so that a requisition should be very carefully considered before it is submitted. There are certain items which can be made efficiently and quickly and certainly more cheaply than they can be bought from laboratory dealers. For example, Wheatstone bridges, potentiometers, vivaria, wormeries, lens holders, observation hives, Berlese Tullgren funnels to mention only a few. The illustrations referred to, are drawings of pieces of apparatus which have been made by men training as teachers. (See figs. 24, 25, 26).

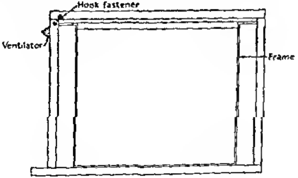

Fig. 24. Observation Hive.

In order to help with this sort of thing and also with some glassblowing, it is desirable that a school should have as part of the science equipment, a wood-work bench, a metal-work bench and a glassblowing table, all fitted with the appropriate tools. The science teacher should be skilled in the use of these.

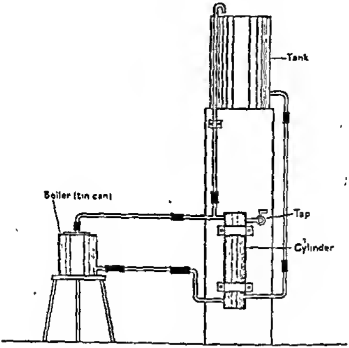

Fig. 25. Model of Domestic Hot-Water System.

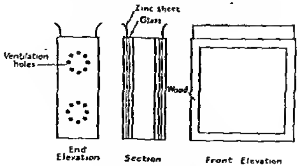

Fig. 26. Wormery.

Further help can also be obtained if there is good co-operation between the science department and the wood- and metal-work department of a school. It should be possible for boys to make certain pieces of apparatus during their lessons in wood-work and metal-work. There must, however, be a proviso that the making of such pieces of apparatus should be part of the wood- and metal-work scheme and that as such they should be worth making as examples of skill in these crafts.

I should deprecate the making of scientific models to the exclusion of other science work. The making of a scientific model by a child must have an educational value either in the form of the teaching of a skill or to learn something of science. For one boy to make a series of models based on the electric motor can easily be a waste of time unless there is a new scientific principle in each model. This is an important point.

Science should be able to help the teaching in wood- and metal-work. A knowledge of the microscopic structure of wood can be gained in science lessons. Children can by this means see, for example, why lime is easy to cut whereas oak is difficult. The chemistry of metals would be helpful in understanding the properties of metals which would assist in the understanding of these metals in metal-work.

C. Science and Art

It is wrong to consider Science and Art as being poles apart. One can help the other.

In biology, it is a good thing if boys and girls can make drawings of plants and animals which resemble the actual things. Some training in the drawing of plants and animals in art lessons would help this. By learning to draw plants and animals children can learn not only the form but the habits of these living things. In the drawing of birds, horses, and dogs it might be possible to indicate something of the individual characteristics. This kind of effect is very evident in certain books.[1] For drawings of plants there are some excellent books.[2]

Good drawings are often better than photographs when we are concerned with living things. It is certainly true that the person who draws an oak tree is more likely to remember its form than one who photographs it. A drawing which is good is a portrait and as such it shows much more than what is taken by a camera in a fraction of time.

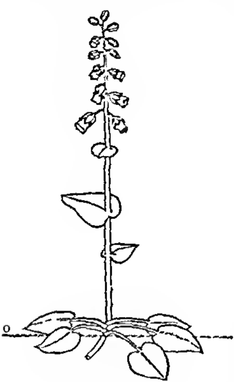

Fig. 27. Partial rosette plant. O—soil surface.

Composite drawings showing associations of plants and animals are useful. When children do these they usually remember something of the association. They might draw the plants and animals which are found in a particular pond. Or they might make drawings of plants found in the garden representing different families.

The use of colour requires careful consideration. Colour should not be applied simply to make a bad drawing look a little more like the actual object. If a drawing is done well colour might be better left out. The drawing may well suggest form, which is more significant than colour. As far as we know colour is peculiar to human beings and in addition is always subjective. So unless the colouring can be done really well, be content with black, grey, and white (see figs. 27, 28, 29).

Drawings in physics and chemistry are best left formal. Sectional drawings are usually the most efficient. They should be clear, and large enough so that each part can be

easily seen. The more difficult drawings can be useful exercises in technical drawing. For example the cylinder of a motor car engine may be considered in science. A sectional drawing of this is a useful exercise in technical drawing.

Lettering is often weak in the labelling of scientific drawings. This is unfortunate because poor lettering can spoil the

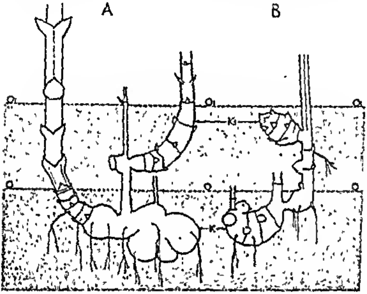

Fig. 28. *Figwort roots, showing two plants which have become covered with a layer of soil.* K_1—New tubers with new winter buds. K—Old tubers. Adapted from Raunkiaer, *The Life Forms of Plants*, by kind permission of the Oxford University Press.

look of the drawing. The letter should be a simple type without serifs or other embellishments. Although it is simple, it requires practice. If the drawing is left in pencil it is often convenient to do the lettering in pencil.

For more permanent drawings however, it is better to line them with Indian ink and carry out the lettering with a broad pen using the script form. Such drawings are as permanent as ever drawings should be. A style of this kind is adaptable for making charts.

Science should also be able to help the Art lesson. A certain

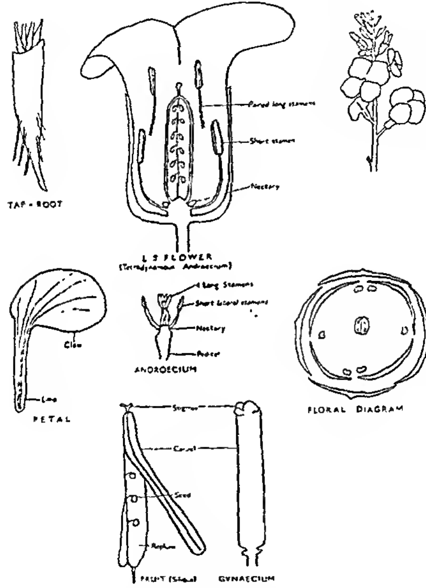

Fig. 29. Wallflower. Adapted from Blodwen Lloyd, *Handbook of Botanical Diagrams*, by kind permission of the University of London Press Ltd.

amount of chemistry can be based on pigments. It is possible by simple experiments to make these in the laboratory.[1] This convinces children that pigments are made from natural materials.

Children might also experiment with some dyes and dye cloth made from different material to compare the effects of say real silk and wool.

It is also good for boys and girls to know how pencils, brushes and paper are made and what chemical properties they possess that make them so useful to the artist. A lesson might be given on the hardness of pencils and how this variation between HH and BB is brought about.

D. Science and Geography

These are two subjects which are closely linked together. Meteorology is a subject which can be taught as a science or as geography. The actual recording of atmospheric pressure, temperatures, wind directions and pressures and rainfall and the study of the recording instruments is science. But the interpretation of the results in terms of climate and its effects on land and man is geography. One subject can very well help the other.

Children can see something of the methods of meteorology and how they are applied to local conditions. Then when climatic effects in other parts of the world are studied they should have an idea as to how they are measured.

The two subjects are again interwoven in the matter of rocks and soils. The way in which the breaking down of different types of rocks produce different soil types is really a science. It is a combination of Geology and Petrology. The erosion of rocks can be considered in chemistry lessons; the action of water on limestone is a firm favourite. Then there are such physical effects as the percolation of the fissures of rocks by water and its subsequent freezing which results in the breaking up of the rock.

The distribution of plants and animals throughout the world is both the concern of the geographer and the scientist. The geographer is really only concerned with their distribution and location according to broad vegetative regions. On

the other hand, the scientist is concerned with the more detailed relationships not only between predator and prey but also with the competition taking place all the time particularly between similar types, commonly called interspecific competition.

I have tried to show here how the two subjects of science and geography can assist each other.

In this chapter an attempt has been made to show how science can be related to other subjects in the school curriculum. These other subjects mentioned can strengthen the power of the science teaching and science for its part can contribute towards these other subjects. This kind of relationship is often referred to as correlation, but it should be remembered that much passes for correlation which is not true correlation.

It is often argued that specialist teaching results in lessons being in water-tight compartments. Some teachers go so far as to say that the class teaching method—when one teacher takes a class for all subjects—is the best because he teaches the children rather than separate subjects, he sees their complete needs. This latter argument would be all right if a teacher was an expert teacher in all subjects, which he very rarely is. With an infant teacher, she knows enough of the subject matter to teach all subjects, so that in this case it is best for the young children to have one teacher all the time. They want a feeling of security which can only be developed by the class teacher method.

For the secondary school child it is good for him to come into contact with the different personalities of a number of teachers. This should be an essential part of his education. The difficulty of co-operation between the different specialist teachers can be overcome by the teachers themselves. The school staff can form itself into a number of panels; they are really small boards of studies. A teacher may be a member of a number of panels. The science panel should have for chairman the science specialist or senior science specialist if there is more than one. Other teachers who might well be members of this panel are those teaching mathematics, rural science,

domestic science, wood-work, metal-work and possibly art. This panel should meet not less frequently than once a month and can consider common problems. Its main purpose is to break down the barriers between different subjects. Always remember that it is the same John Smith who takes Science from 11.0 to 12.0 on Monday, Rural-Science from 1.30 to 4.0 on Thursday and Art on Wednesday from 3.0 to 4.0.

SUMMARY

A. Science and Mathematics.

B. Science and Handicrafts.

C. Science and Art.

D. Science and Geography.

REFERENCES (CHAPTER NINE)

[1] E.g. E. A. R. Ennion, *The Lapwing*.

[2] E.g. Ross Craig, *Drawings of British Plants* (Bell).

[3] See *Science Masters' Book:* "Making of Pigments". Series II, Vol. II.

CHAPTER TEN

THE SCIENTIFIC SOCIETY AND SCIENCE VISITS

Membership of the Scientific Society should be available to any children in the school irrespective of whether they are still doing science. In many schools all the children do science throughout their school careers, but in the schools visualised in this book, it is possible that with a choice of study courses some children may not do science in lessons after the age of 13.

School societies are sometimes not organised, because the children have to go home by school buses. In such cases it may be possible for children to attend school societies in the dinner interval. There is also the possibility that one or more periods per week in the school time-table can be given over to school societies. During this period children will choose which society they are going to attend. Whilst too much fluctuation between society and society is not desirable it is not necessary for children to keep to the same society each week. This system of devoting one period per week in school time can work very well. There should, in addition, be meetings outside the time-table in order to encourage voluntary participation.

A. Organisation of the Scientific Society

The Scientific Society should be organised so that it runs efficiently. It is desirable for the Head Teacher to be the President of the Society and he should take as active a part in the Society as time will permit.

Then there should be advisers from among the staff. The teachers of science should be the advisers. The extent to which they help to run the organisation will depend on the capacity of the children to run it.

The Chairman of the Scientific Society should be a senior child with ability in leadership and with initiative. He will

hold a key position in the Society and as a result much of the success of the Society will depend upon him or her.

The Secretary should be a child keen on science and energetic. This position is second only to that of the Chairman. He should be capable of taking minutes, carrying out the instructions of the committee and generally helping the Society to run smoothly.

Since it costs money to run a Scientific Society, it is useful to have a treasurer. He should be a good arithmetician and should generally be guided by one of the Staff advisers. The money he will handle will be the children's subscriptions to the society. Whilst capital expenditure on the society should be borne by the school, there are certain items best met from children's subscriptions. Children usually value something better when they have to pay a little.

The rest of the committee can usefully be made up by a representative from each form. These can be elected either annually or terminally, though it will probably be better to elect them annually.

It might also be useful to have a publicity agent. He or she should make the activities of the society known to all the children in the school. A child with artistic talents would be able to design suitable posters for this purpose.

B. *Functions of the Committee*

The committee will have a number of functions. In the first place it should arrange meetings at regular intervals. All details of these meetings should be worked out so that they run smoothly. As a rule the secretary will make the arrangements, acting on the decisions of the committee.

There will be certain visits out of school hours to be arranged. This will include getting permission, arranging buses where necessary, obtaining advance information about the places to be seen, ensuring an adequate supply of food and remembering to thank the people concerned.

The society should also have a small library of scientific books, but not school books. It is part of the purpose of the committee to choose the books to form the library.

The fourth function is the arranging of a club room. If possible, this should be more like a club room than a classroom, though this will largely depend on the school facilities.

C. Meetings

Meetings can take a number of forms; I will suggest five kinds of meetings:

Children can give talks to the society. This can either be done by short papers when three or four children will talk for five minutes each at one meeting or in the case of a bright child, he might take up the whole meeting. Where possible these talks should be illustrated with demonstrations. The demonstrations may take several forms. In some cases the talk can be illustrated by a practical demonstration with apparatus. Then there is illustration by lantern slides, the micro-projector, the episcope or by means of pictures of various kinds. There may also be illustration with models. The type of illustration will depend on the subject. An important feature of these meetings will be the discussions after the actual talk.

The next kind of meeting is that where the teacher does the talking and carries out the demonstration. Since the children hear their teacher so much in the course of lessons, I would suggest that this type of meeting should be reduced to a minimum. Teachers who talk at these meetings should avoid dealing with subjects normally considered in lesson time. They should choose something more recreational such as "Chemical Magic"; "Television"; "How musical instruments make their sounds"; "Do animals think"; "Is it true that boys are more interested in animals than in plants?"

Then there are meetings where outsiders talk. A visit to the gas works may be followed up by a talk in school by the local works manager or a visit to a chemical works may be followed up by a talk by a chemist from the works, or a visit to a large nursery may be supplemented by an address by a gardener who works at the nursery. In some cases it is best for the talks to precede the visit and in other cases to follow the visit. Here again illustrations to the talk are most helpful.

Scientific societies should have periodical exhibitions. These should be held once or twice a year. There can well be an exhibition of scientific toys to include such items as electric motors, Meccano models, electric trains, steam engines, a "shocking" coil, clay models, and aquaria. Or an exhibition of pets can be arranged. This may include butterflies, beetles, mice, rabbits, guinea-pigs, snakes, pigeons, canaries and goats. Another type of exhibition is that which is the culmination of a number of competitions such as pressed wild flowers, model filter plant, collection of beetles, collection of galls,[1] plaster casts of footprints[2] and data about migrant insects.[3] There could also be an exhibition of nature photographs including those taken by the children and photographs cut out of journals and newspapers.

The last type of meeting I wish to mention is that at which films are shown. Whereas films will be shown in connection with lessons, it is also good to show films at some of the society meetings. It is here where films that do not illustrate specific lessons can be shown. When a number of films are shown on a particular evening, time should be found for film discussion. It is part of education to train the critical sense of children and this provides a good opportunity.

D. Visits

Visits can be of several kinds. Let us first consider nature rambles. These can be undertaken from an Ecological standpoint. Such types as ponds, streams, oak woods, beech woods, heaths, sand dunes, the sea-shore, marshes, and hedgerows may be visited. Local experts may be brought in to help; these will include botanists, entomologists, aquarists and ornithologists. Since more time can be taken over nature rambles out of school hours than can be given to them in school time, there is considerably more value to be gained from the former than can be gained from the latter. Not only is that so, but the rambles can be made more informal and also more of a social occasion. A picnic meal may be taken which always adds to the pleasant nature of a ramble. Nature rambles should not be undertaken without

appropriate equipment such as collecting boxes, beating trays, vascula, pond nets and pond sieves, butterfly nets, killing bottles, relaxing tins and drag nets.

It may also be possible to arrange visits to Bird Sanctuaries and Fish Hatcheries. In many bird sanctuaries it is possible to see birds not seen as natives. Although it is important to consider local environment, it is nevertheless desirable to relate it to world matters. This applies to Biology as well as to Geography and History. Fish hatcheries provide opportunities for studying the breeding of fishes on a large scale. It is here where two-headed and two-tailed young trout may be seen.

There may also be visits to factories, foundries and public utility services. These will supplement visits made in school time. It is convenient for the Scientific Society to visit places which would not normally be visited in connection with the general science course. Since these will differ very much from school to school it is difficult to specify particular places.

Visits to laboratories, a B.B.C. Transmitting Station and a cinema projector are examples of another type of visit. In choosing a laboratory visit, care should be taken that what the children are to see and hear is not too difficult for them. Laboratory work has become so specialised in many cases that great care needs to be taken. Children will be interested to see the commercial cinema projector and compare it with the school projector. The B.B.C. transmitter is fascinating particularly for boys, the great masts, the banks of generators and the massive valves arouse keen interest.

Some night visits may possibly be arranged. If it is known where there are badgers, it will be of value to take small groups of children to watch for "brock". They are attractive mammals[4] which are much maligned. It is a pity that animals are killed off without due regard to their natural interest just because they are thought to do damage to crops and livestock when real proof is not forthcoming. In connection with badgers it may be possible for the children to photograph the animals.

Night insect watching is useful. Here we can attract moths

by means of treacle on tree stumps or by the aid of a hurricane lamp and a white sheet behind it. The insects to be found at night differ significantly from those found during daylight hours.

The Scientific Society should also visit farms of the best types. They may so far as is possible see stock raising, dairy farming and crop growing. Milk and egg production are also worth considering. It is, of course, desirable to visit a farm at different seasons to see the various processes in action; this is particularly applicable to arable farming. The processes of ploughing, hoeing, dragging, manuring, liming and harvesting should be seen in turn. If possible a farm growing crops like wheat, barley, oats, and peas and root crops should be compared with one growing fruit like apples, gooseberries etc. The cycle of events in a dairy farm or stock raising farm are perhaps not quite so distinctive, but are there nevertheless. There are such annual phases as lambing, sheep-shearing, sheep-dipping, calving, incubation of eggs and so on. In fact there is a wealth of material to be found on good farms.

The last type of visit I wish to consider is concerned with competitions. A scientific society may wish to carry out friendly cattle judging. A good farmer will give hints on judging cattle and then the children can try their hand at arranging say four cows in order of merit. They should be able to place them according to definite merit points and each child should give reasons for this choice of arrangement. This kind of competition is very well organised by Young Farmers' Clubs and science teachers who are keen on visits of this kind would do well to get into touch with the local Young Farmers' Club. There are other competitions such as rabbit judging, arranging wild flowers in a vase, judging tomatoes, arranging eggs in order of merit and so forth.

E. *Library and Museum*

Members of the Scientific Society should have access, because they are members of the school, to the school library. Here they can consult text-books and reference books. It is

an important part of school training for the children to be able to find information when they want it. The scientific society will touch topics not taken in lessons and this is good, because it encourages children to look for information of all kinds.

Scientific classification can be learned in no better way than in the process of identifying insects brought in from a nature ramble. With practice and thought children learn how to group insects first into orders, then into families, later into genera and finally into species. They learn to differentiate insects by minute differences. It is a splendid training in observation.

In doing this work, children learn to use reference books of various kinds on insects.[5] There are quite a number of these and they should be in a good school library. If children learn to study reference books, first by following the text and then checking the identification by references to a drawing, or photograph, they have learned a valuable process in scientific method.

There should be reference books of various kinds. Astronomy is often a popular subject; books dealing with stellar measurements and giving star maps are of interest. Books on aerodynamics and various kinds of engineering such as mechanical, motor and electrical will certainly appeal to boys. Then there are reference books on metals, chemical substances, physical constants and the like. There are dictionaries of plants and animals. In addition it should be useful to have books on geology. In the chapter on The Science Library these matters are dealt with more fully.

There should also be a good stock of more readable books on science. These may include Fabre's works on Insects, Crompton's *The Hunting Wasp*, Maeterlinck's *The Bee*, Lankester's *Fire Side Science* and similar books. For the brighter children the New Naturalist Series[6] of books are helpful. There are quite a number of natural history books on the market of varying quality; a careful selection of these should be made.

Then there should be books dealing with the wonders of mechanics and other forms of engineering. Books on Astro-

nomy in the more popular vein have their appeal. Also books on various aspects of farming should be in the library.

Another feature of the Society's Library and Museum should be a collection of pictures, charts and diagrams collected by the members. In the course of a number of years, a

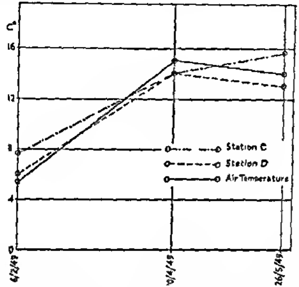

Fig. 30 Graphs showing the relation between the Air and Water Temperatures at the Noverton Lane stream stations.

society should amass quite an interesting collection of such illustrative material. Pictures can be obtained from all kinds of sources such as journals, newspapers, advertisements and books. There should also be room for efforts by the children themselves. Charts using graphical methods of all kinds can be a useful feature. Records which are made on natural history visits can be graphically illustrated in many striking ways. I have given an example by way of illustration (fig. 30).

Diagrams, by which we usually mean symbolic drawings of various kinds, can also be useful. Members of the society can be encouraged to make these; in fact periodic competition would give zest to this kind of work. Diagrams in which

three dimensions are indicated formally are most effective (see Plate II, facing page 200).

There should also be a place in the Society Library for the collected notes and specimens obtained by members. It ought to be possible to get together a representative collection of insects, pressed plants and rocks of the district. Then there may be a collection of mosses, lichens, leafprints, and bark rubbings.[7] In this section we might also have bones, particularly skulls. A selection of bird pellets carefully dissected is most enlightening. Nor must we forget samples of the various products of industry in the district. If the school is situated in a textile town, why not have a collection of the raw fibres, say cotton, and examples of threads and woven cloth? Pictures, diagrams and models of the machinery used in the manufacture of the cloth would add to the completeness of the section.

Finally it ought to be possible to have a certain number of scientific periodicals and journals. There should be care in the selection of these because many are far too difficult for the children to understand. These should so far as is possible cover the varied interest of the children. Periodicals with plenty of illustrations appeal to the children more than those without. Applied sciences, including farming, should not be forgotten in this connection.

F. Science Club Room

Although most schools will not have enough accommodation for a science club room, it is worth considering. It may be that the Scientific Society will have to share a room with a number of other School Societies and arrange to use the room in consultation with the other societies. What I am now about to describe may sound rather idealistic at present.

The Science Club room should be a room where there can be informal chats about science apart from the normal society meetings. It should have a suitable collection of pictures round the walls. These should be changed from time to time so that they do not become just part of the wall topography.

It would also be desirable to have the Scientific Society

continued into a Senior Scientific Society formed of old students. This Society might well meet in the same room.

If possible the room should be much more informal than a classroom. It might be as well to have chairs without desks or individual tables.

G. The Place of the Young Farmers' Club

It will probably not be possible to have both a Scientific Society and a Young Farmers' Club as separate entities in the same school. I think a combined club is better. In what has been written in this chapter, the Young Farmers' Club side has not been forgotten. All children will not be interested in this side of the society, but that does not really matter. The best farming is applied science so that really the Young Farmers' Club can be considered a branch of the Scientific Society.

The Young Farmers' Club will be specially concerned with the school livestock; visits to farms; the judging of livestock; public speaking competitions and local and county rallies.

H. Wireless Transmitting Club

A wireless course included in the school curriculum may well lead to the formation of a wireless club. At first it may just be a club which makes receiving sets. The receiving sets can be built according to the principles laid down in the Science Course. Then the club may become more ambitious and launch out on becoming a transmitting club. This will no doubt make a considerable demand upon the school funds, though there appears to be no reason why the Local Education Authority should not help to finance the project.

The members of the club will get a great thrill out of assembling the components and setting up the equipment. When the set is completed, then the members will need to learn the morse code and pass a test in order to qualify to transmit.

Once the station is established the members of the club will get considerable interest out of conversations with people

in many distant parts of the world. This will help them to understand other people better. It should encourage them to learn foreign languages.

I have given suggestions on the organisation of a School Scientific Society. It is doubtful whether all my suggestions can be carried out in one school, but any school desirous of trying out the ideas, can make a selection from these suggestions.

Summary

A. Organisation of the Scientific Society.

B. Functions of the Committee.

C. Meetings.

D. Visits.

E. Library and Museum.

F. Science Club Room.

G. The Place of the Young Farmers' Club.

H. Wireless Transmitting Club.

References (Chapter Ten)

[1] E. W. Swanton, *British Plant Galls*, 1912.
E. T. Connold, *British Vegetable Galls*, 1901.
E. T. Connold, *British Oak Galls*, 1908.

[2] Nature Study Leaflets. Nos. 15, 16, 23, "Nature Tracking" by A. Hibbert-Ware. 4d. (Obtainable from Mr A. C. Funnell, 23 Crystal Palace Road, East Dulwich, S.E.22.)

[3] C. B. Williams, *Butterfly Migration* (Daily Mail School Aid Publication). 1s.

"British Immigrant Butterflies and Moths" (Set E 57). (British Museum.) 1947.

Migration Records, 1947, by Capt. T. Dannreuther, R.N. reprinted from *The Entomologist*, April, 1948, Vol. LXXXI, pages 73-83.

Secretary of Insect Immigration Committee of the S.E. Union of Scientific Societies is Captain T. Dannreuther, Windycroft, Hastings.

[4] E. G. Neal, *The Badger* (Collins).

[5] Reference books on Insects.

Consult Book List of Amateur Entomologists' Society, 1 West Ham Lane, London, E.15.

Also bibliographies of: A. D. Imms, *Insect Natural History* (Collins). A. D. Imms, *General Textbook of Entomology* (Methuen).

[6] New Naturalist Series of Books (Collins):

E. B. Ford, *Butterflies*.

Brian Vesey-Fitzgerald, *British Game*.

R. S. R. Fitter, *London Natural History*.

F. Fraser Darling, *Natural History in the Highlands and Islands*.

L. Dudley Stamp, *Britain's Structure and Scenery*.

A. S. Imms, *Insect Natural History*.

W. B. Turrill, *British Plant Life*.

C. M. Yonge, *The Sea Shore*.

The New Naturalist, *A Journal of Natural History*.

Also W. J. Prud'homme van Reine, *Plants and Animals of the Sea-Shore* (John Murray).

[7] See Article by Miss Vinnecombe in *The School Nature Study Journal*, No. 174, Vol. 44, January, 1949.

CHAPTER ELEVEN

THE SCIENCE LIBRARY

This subject has already been considered to some extent in chapter 10. In this chapter the subject will be expanded. The science library can usefully be divided between two places:

1. The General School Library.
2. The Science Department Library.

I will deal with these separately.

A. The General School Library

There should be in this library a number of science reference books as well as general reference books containing scientific topics. In the former category may be included an encyclopaedia of gardening, whereas in the latter would be included a general encyclopaedia, or Whitaker's Almanac. Some reference books, such as books giving physical and chemical constants, would be more useful in the Science Department than in the General Library. In this case the best policy is to get two copies, one for the General Library and one for the Class Library of Science. Reference books need to be of good quality even more than other books, because they are sources of information and this must be reliable. These books are consulted for practical knowledge which is usually assumed to be correct. Before buying a science reference book it is desirable to check it for one or two difficult subjects like isotope, genes, unsaturated fatty acid, nebula, and Piltdown man against a standard work on these subjects or the *Encyclopaedia Britannica* which can usually be relied upon. It might be useful to tell children how to do this. The general library scientific reference books, where only one copy is available, should be of a type not normally required in laboratory or field work. Boulenger's *Apes and Monkeys*, for example, is of this type for the obvious reason that such animals are not likely to be met with in a field excursion. It

may be allowed to be used in the Scientific Library when a group of children is proposing to visit a Zoo as part of the school work.

The General Library should also contain a selection of good text-books. I use the word 'good' advisedly because there are so many text-books of rather a hum-drum type. We want children to read text-books because they find them interesting. In this connection I would recommend the inclusion of text-books from other countries, particularly France, Germany and U.S.A. The advantage of including text-books from other countries lies in the fact that you can compare them from various points of view such as method, subject matter, illustration and general lay out.

The library should also contain books of a more readable nature in that the narrative is mostly continuous and the facts of science are clothed with story or other imaginative forms. We do not usually read text-books for pleasure, so we should not expect the children to do this. There are books of a readable nature in which the facts are correct, but the text is such that they can be read for recreation. A number of these should be included.

The General Library should have a Card-index reference system based on Modern Library Technique so that books may easily be located either by subject or author. Learning how to use such a system is good training in classification which after all is really part of scientific method. To know how to find books and, what is more, to know how to find information is most valuable training.

B. The Science Department Library

This should contain useful reference books. One group should be for the purpose of identifying natural history specimens. There is a large range of these books of which details are given at the end of the chapter. When getting books of this kind for the school library care should be taken that they are authoritative. Some reference books are useless for one or two reasons. Either the method of identification is not scientific or the book contains coloured plates which

are not coloured true to the specimens they intend to represent. Black, grey and white drawings, provided they are well drawn, are better than badly coloured ones. In the case of certain iridescent butterflies and other insects it is impossible to produce coloured plates which are sufficiently accurate.

Then it is necessary to have books of experiments. Some will give variations of experiments to test laws like Ohm's law, Graham's Law, Law of Multiple proportions or the Gas Laws. Others will provide experiments to illustrate in a laboratory fashion such installations as the internal combustion engine, the steam engine, the household water system, the household electric system, the dynamo and the pelton wheel. Then again, there will be experiments to illustrate certain scientific processes like osmosis, photography, hysteresis, electrical dissociation and thermal dissociation. There should also be books of preparations, so that it is possible to find out how to make various chemicals such as cuprammonium sulphate, cupric acetate, iodoform and stannous chloride.

In the science class library we should also have books of data so that we can find physical and chemical constants quickly. We may wish to know the boiling point of ethyl alcohol at Normal Pressure. Or we may desire to know the melting point of Camphor. It may be necessary to find the value of the vapour pressure of water at a certain temperature. In these days of atomic physics we may wish to have some information about isotopes.

The science class library should also contain a number of standard text-books of various kinds. Only the best should be chosen. These should be books to which the children will turn for the type of information they will require in the ordinary course of events. Such books should be readily accessible so that children can turn to them when engaged in practical work in the laboratory or during such free time as the dinner interval. In the matter of text-books it is important that they are kept up to date by periodically scrapping those which are outdated and replacing them by new ones.

Finally it may be possible in the course of time for teachers

to produce typewritten notes on experimental work of various kinds. These can be kept in suitable folders and will be accessible for guidance in doing practical work. A good science teacher can gradually build up an excellent set of practical notes of this type on various science subjects.

The remainder of the chapter will be taken up with a bibliography of science books suitable for the purposes I have mentioned. It is not meant to be exhaustive, but will give teachers some indication of the kinds of books suitable for science in the Secondary Modern School.

BOOKS FOR A SECONDARY MODERN SCHOOL SCIENCE LIBRARY*

References: G = Suitable for General Library.
S = Suitable for Science Class Library.
R = Reference.
T = Text-book.
r = Suitable for reading as a continuous narrative.
s = simple.
m = medium standard.
a = advanced.

Abbreviations: S.M.A.—Science Masters' Association
I.A.A.M.—Incorporated Association of Assistant Masters

1. History of Science

Crowther, J. G.	*British Scientists of the Nineteenth Century*. 2 vols. 1s. 6d. each	Penguin G R m
Crowther, J. G.	*Famous American Men of Science* 2 vols. 1s. 6d. each	Penguin G R m
Dampier, W. C.	*A Shorter History of Science* 7s. 6d.	Cambridge G r m
Farrington, B.	*Greek Science* 2 vols. 1s. 6d. each	Penguin G r m
Gregory, R.	*British Scientists*. ("Britain in Pictures" Series). 5s.	Collins G r s

* N.B. See note following Preface (p. iv).

Hart, I. B.	*Makers of Science* 7s. 6d.	Oxford G r m
Libby, W.	*Introduction to the History of Science.* 5s.	Harrap G
Pledge, H. T.	*Science since 1500* 10s.	H.M.S.O. G r m
Reason, H. A.	*The Road to Modern Science* 8s. 6d.	Bell G r m
Singer, C.	*A Short History of Science to the Nineteenth Century.* 12s. 6d.	Oxford G r m
	Historical Apparatus. (S.M.A. Modern Science Memoir No. 8). 6d.	Murray G r m

2. Science in General

(a) Social Relations

Ashby, E.	*Scientist in Russia* 1s. 6d.	Penguin G r m
Baker, J. R. and Haldane, J. B. S.	*Biology in Everyday Life* 3s. 6d.	Allen & Unwin G r m
Clark, F. Le Gros	*Feeding the Human Family* 7s. 6d.	Sigma Books G r m
Curtis, F. D., Caldwell, O. W. & Sherman, N. M.	*Everyday Biology* 15s. 6d.	Ginn G r m
Dingle, H.	*Science and Human Experience* 7s.	Williams & & Norgate G r m
Findlay, A.	*Science and the Community* 1s.	Whitcombe & Tombs G r m
Hatfield, H. S.	*The Inventor and his World* 1s. 6d.	Penguin G r m
Hogben, L.	*Science for the Citizen* 16s.	Allen & Unwin G r m
McDowall, S. G.	*Biology and Mankind* 6s.	Cambridge G r a
Orr, J. (Ed.)	*What Science stands for* 5s.	Allen & Unwin G r m

Read, J.	*The Alchemist in Life, Literature and Art.* 10s. 6d.	Nelson G r m
Richardson, E. G.	*Physical Science in Art and Industry* 15s.	Eng. Univ. Press G r a
Richardson, E. G.	*Physical Science in Modern Life* 10s. 6d.	Eng. Univ. Press G r a
Taylor, F. S.	*Science Past and Present* 10s. 6d.	Heinemann G r m

(*b*) Popular General Science

Andrade, E. N. Da C.	*Engines* 9s.	Bell G r m
Andrade, E. N. Da C.	*The Mechanism of Nature* 7s. 6d.	Bell G r m
—	*Vibrations and Waves* 12s. 6d.	Bell G r m
Andrade, E. N. Da C. and Huxley, J.	*Simple Science* 12s. 6d.	Blackwell G r s
Andrade, E. N. Da C. and Huxley, J.	*More Simple Science* 8s. 6d.	Blackwell G r s
Arrhenius, S. A.	*Chemistry in Modern Life* 16s. 6d.	Macmillan G r m
Bagley, W. A.	*The Boys Book of Metalcraft* 3s. 6d.	Vawser & Wiles S R m
Bagley, W. A.	*Things to make and do* 3s. 6d.	Vawser & Wiles S R m
Barnard, J.	*The Handy Boy's Book* 5s.	Ward, Lock & Co. S r m
Boothroyd, F.	*How and Why it works* Parts 1 & 2 3s. 6d. each. Part 3 3s. 9d.	Schofield & Sims S R s
Bragg, W. H.	*Old Trades and New Knowledge* (Royal Institution Lectures) 4s. 6d.	Bell G r m

Browning, G. M.	*Botany for Fun* 6s.	Lindsay Drummond G r m
Chase, C. T.	*Children's Questions: The Parents' Book of Answers.* 3s. 6d.	Nelson G r m
Crowther, J. G.	*An Outline of the Universe* 1s. 6d.	Penguin G r m
Cullis, W.	*Your Body and how it works* 2s.	Allen & Unwin G r m
Cullis, W. and Bond, M.	*The Body and its Health* 5s.	Allen & Unwin G r m
Elliott, F. F.	*Electrical and Mechanical Model Making* 2s. 6d.	Univ. London Press S r m
Firth, J. B.	*Chemistry in the Home* 2s.	Constable G r m
Freeman, M. & J.	*Fun with Chemistry* 7s. 6d.	Pilot Press G r m
Gamow, G.	*Mr. Tompkins in Wonderland* 10s. 6d.	Cambridge G r m
Gamow, G.	*Mr. Tompkins explores the Atom* 10s. 6d.	Cambridge G r m
Gibson, C. R.	*Romance of Scientific Discovery* 6s.	Seeley Service G r m
Gibson, C. R.	*Romance of Coal* 6s.	Seeley Service G r m
Gibson, C. R.	*Scientific Ideas of Today* 6s.	Seeley Service G r m
Haldane, J. B. S.	*Science Advances* 10s. 6d.	Allen & Unwin G r a
Harrison, J.	*Engines Today* 7s. 6d.	Oxford G r m
Hartridge, H.	*Colours and how we see them* (Royal Institution Christmas Lectures, 1946-7) 15s.	Bell G r m

Haslett, A. W.	*Radio round the World* 6s.	Cambridge G r m
Hawks, E.	*How it Works and how it's Done* 8s. 6d.	Odhams S R m
Hill, A. V.	*Living Machinery* 7s. 6d.	Bell G r m
Howard, E. D. (Ed.)	*Modern Foundry Practice* 8s. 6d.	Odhams S R m
Kendall, J.	*At Home among the Atoms* 8s. 6d.	Bell G r m
Kermack, W. O.	*The Stuff We're made of* 10s. 6d.	Arnold G r m
Low, A. M.	*Science Looks Ahead* 12s. 6d.	Oxford G r m
Low, A. M.	*Science in Industry* 7s. 6d.	Oxford G r m
Low, A. M.	*Popular Scientific Recreations* 8s. 6d.	Ward, Lock G R m
Low, A. M.	*The Way it Works* 8s. 6d.	Peter Davies G R m
Norris, R. C. (Ed.)	*Principles of Electricity* 8s. 6d.	Odhams S T m
Oakley, W.	*The Boy's Workshop Companion* 8s. 6d.	Lane S T m
Partington, J. R.	*Everyday Chemistry* 12s. 6d.	Macmillan S T m
Plimmer, R. H. & V. G.	*Food, Health & Vitamins* 7s. 6d.	Longmans G r m
Ranshaw, G. S.	*The Boy's Book of Modern Scientific Wonders.* 8s. 6d.	BurkePub.Co. G r m
Ranshaw, G. S.	*The Boys Book of How Things are Made.* 10s. 6d.	Burke Pub. Co. G r m
Ranshaw, G. S.	*The Boy's Book of Radio, Television and Radar.* 10s. 6d.	Burke Pub. Co. G r m
Ranshaw, G. S.	*New Scientific Achievements* 6s.	Burke Pub. Co. G r m
Roberts, J. E.	*A Year with Nature* 3s. 6d. (with coloured plates 6s.)	Arnold G r s

Robertson, J. H.	*The Story of the Telephone* 10s. 6d.	Pitman G r m
Robins, F. W.	*The Story of the Lamp* 15s.	Oxford G r m
Rowland, T. J. S. and Smith, L. G.	*Living Things for Lively Youngsters.* 7s. 6d.	Cassell G r s
Rowland, T. J. S. and Smith, L. G.	*More Living Things for Lively Youngsters.* 7s. 6d.	Cassell G r s
Rowland, T. J. S. and Smith, L. G.	*Everyday Things for Lively Youngsters.* 7s. 6d.	Cassell G r s
Rowland, T. J. S. and Smith, L. G.	*Vital Things for Lively Youngsters* 7s. 6d.	Cassell G r s
Rowland, T. J. S. and Smith, L. G.	*Moving Things for Lively Youngsters.* 7s. 6d.	Cassell G r s
Salisbury, E. J.	*The Living Garden* 6s.	Bell G r m
Sanford, J. C.	*Wonderland of Science* 12s. 6d.	Virtue G r m
Singer, G.	*The Circulation of the Blood* 2s. 6d.	Bell G r m
Solomon, A. K.	*Why smash atoms?*	Oxford 16s. Penguin 1s. 6d. G r m
Spencer-Jones, H.	*Astronomy in Daily Life* (Royal Institution Christmas Lectures, 1944-5). 12s. 6d.	Bell G r m
Sumner, W. L.	*Progress in Science* 8s. 6d.	Blackwell G r m
Taylor, F. S.	*The World of Science* 8s. 6d.	Heinemann G r m

VARIOUS AUTHORS

	Everyday Knowledge in Pictures 7s. 6d.	Odhams G r m
	Triumphs of Engineering 7s. 6d.	Odhams G r m
	The Marvels and Mysteries of Science. 8s. 6d.	Odhams G r m

VARIOUS AUTHORS—*contd.*

How and why it works	Odhams
9s. 6d.	S r m
The Miracle of the Human Body	Odhams
8s. 9d.	S R m
The Miracle of Man	Odhams
8s. 6d.	S R m
Wonders of Nature	Odhams
7s. 6d.	G r m
The Science of Living Things	Odhams
7s. 6d.	G r m
Practical Automobile Engineering	Odhams
10s. 6d.	S R m
Practical Mechanics for All	Odhams
9s. 6d.	S R m
Internal Combustion Engines	Odhams
9s. 6d.	S R m
Electric Motors and Generators	Odhams
9s. 6d.	S R m
Practical Plastics	Odhams
10s. 6d.	S R m
Practical Radio Reference Book	Odhams
8s. 6d.	S R m

(c) SERIES OF SCIENCE TOPICS

"Background Science" Nelson. 3s. each.

Lauwerys, J. and Glover, A. H. T.	*Making Light*	G r s
Lauwerys, J. and Glover, A. H. T.	*Man and Metals*	G r s
Lauwerys, J. and Glover, A. H. T.	*The Thirst of Cities*	G r s

"Everyday Science Topics". Harrap.

Tweddle, T. A.	*Everyday Science Topics* Part 1, 2s. 3d.; Part 2, 2s. 9d.; Part 3, 3s.	S R s

"How and Why" Books. Black. 3s. 6d. each.

Steavenson, W. H.	*Suns and Worlds*	G r m
Sullivan, J. W. N.	*How things Behave*	G r m

"Life and Science" Series (Ed. P. Thornhill). Methuen. 2s. 3d. each.

Elwell, F.	*Light and Sight*	G r s
Gubbin, G. M.	*The Current we use*	G r s
Holmes, B. & M.	*Keeping Warm*	G r s
Holmes, B. & M.	*The Food we eat*	G r s
Holmes, B. & M.	*The Water we use*	G r s
Moore, W. G.	*The Soil we live on*	G r s
Palmer, R.	*Life Keeps on*	G r s
Thornhill, P.	*The Air we Breathe*	G r s
Thornhill, P.	*Work and Rest*	G r s

"Men and Women at Work" Series. Oxford.

Burr, M.	*The Story of Gold.* 1s. 4d.	G r s
McKay, H.	*Oil.* 1s. 3d.	G r s
McKay, H.	*Rubber and its many Uses.* 1s.	G r s
Wise, C.	*The Story of Transport.* 1s. 6d.	G r s

"New Playbooks of Science." Oxford. 5s. each.

McKay, H.	*Fun with Mechanics*	G r m
McKay, H.	*The Tricks of Light and Colour*	G r m
McKay, H.	*Toys and Inventions*	G r m

"Pageant of Progress" Series. Oxford. 7s. 6d. each.

Allcott, A.	*Chemistry Today*	G r m
Bowman, J.	*Water Supply Today*	G r m
Briggs, M. S.	*Building Today*	G r m
Chapman, E. H.	*Wireless Today*	G r m
Cressy, E.	*Civil Engineering Today*	G r m
Dearden, J.	*Iron and Steel Today*	G r m
Harrison, J.	*Engines Today*	G r m
Harrison, J.	*Motor-Cars Today*	G r m
Keyston, J. E.	*Naval Science Today*	G r m
Nayler, J. L. & Ower, E.	*Flight Today*	G r m
Smart, W. M.	*Astronomy Today*	G r m
Spencer, D. A.	*Photography Today*	G r m
Spencer, D. A. Waley, H. D.	*The Cinema Today*	G r m
Tarr, J. C.	*Printing Today*	G r m
Vinycomb, T. B.	*Electricity Today*	G r m

"Puffin Picture Books." Penguin. 2s. 6d. each.

Alexander, J.	*The Story of Plant Life*	G r s
Bassett-Lowke	*Waterways of the World*	G r s
Bassett-Lowke and Mann	*Marvellous Models*	G r s
Bodmin, S. R.	*Trees in Britain*	G r s
Boulenger, E. G. and Jeremy, P.	*Wonders of Sea Life*	G r s
Chopping	*Butterflies in Britain*	G r s
Edwards, L.	*Our Horses*	G r s
Gardner, J.	*On the Farm*	G r s
Hart, P. M.	*The Magic of Coal*	G r s
Hawkins, S.	*Animals of Australia*	G r s
Holland and Jones	*A Book of Insects*	G r s
Johnson	*Animals of North America*	G r s
Ladyman, P.	*About a Motor-Car*	G r s
Millard and Fisher	*Birds of the Village*	G r s
Pinner, E. and Shorten, M.	*Wonders of Animal Life*	G r s
Richards, A.	*Pond and River Life*	G r s
Stebbing, H.	*Extinct Animals*	G r s
Venables, B.	*Fish and Fishing*	G r s
Wilson, M.	*Dogs*	G r s

"Realms of Natural Science" Series. Oxford. 5s. each.

Ennion, E. A. R.	*The British Bird*	G r m
Plant, E.	*Man's Unwritten Past*	G r m
Richmond, W. K.	*Wild Animals of Britain*	G r m
Savory, T. H.	*Animals*	G r m

"Science in Action" Series. Pitman. 2s. 3d. each.

Claremont, C. A.	*Spanning Space*	G r m
Lawson, R.	*Films in the Making*	G r m
Murray, D. S.	*Man against Disease*	G r m
Randell, W. L.	*Conveying the World's Messages*	G r m
Whyte, A. G.	*Divers and Diving*	G r m

"Science in Everyday Life" Series. Pitman.

Little, W. B.	*Science and Health.* 3s. 6d.	G r m
Little, W. B.	*Science and Living Things.* 5s.	G r m
Little, W. B.	*Science and the Weather.* 2s. 9d.	G r m

"Science in Everyday Life" Series. Pitman—*contd.*.

Little, W. B.	*Science in the City.* 3s.	G r m
Little, W. B.	*Science in the Country.* 3s.	G r m
Little, W. B.	*Science in the Home.* 3s.	G r m
Machin, R. E.	*Science in a Coalfield.* 3s.	G r m
McDougall, A. T.	*Nature's Giant Forces.* 2s. 3d.	G r m
McDougall, A. T.	*Nature's Mystic Movements (Heat Light and Sound).* 3s.	G r m G r m
McDougall, A. T.	*Nature's Wondrous Laws.* 3s.	G r m
McDougall, A. T.	*The Marvels of Chemistry.* 3s. 6d.	G r m
McDougall, A. T.	*The Wonders of Electricity.* 2s. 9d.	G r m
Taylor, H. E.	*Wonders of the Earth's Crust.* 2s. 9d.	G r m
Taylor, H. E.	*Wonders of the Universe.* 2s. 6d.	G r m

"Science Topics" (Ed. G. H. Leslie). Cassell. 3s. 6d. each.

Allcott, A.	*Coal and its Treasures*	G r m
Allcott, A.	*Pumps*	G r m
Pearson, F. J.	*Our Food*	G r m
Rowland, T. J. S.	*Burning and Breathing*	G r m
Rowland, T. J. S.	*Our Senses*	G r m

"Visual History of Mankind" Series. (Ed. by L. Mogden) Parrish (and Harrap). 3s.

	Living in Early Times	G r s
	Living in Villages and Towns	G r s
	Living in the World	G r s

"Young Observers" Series. Cassell. G r s

Allcott, A.	Book 1, 2s. 9d.; Book 2, 3s.; Book 3, 3s. 3d.; Book 4, 3s. 3d.; Book 5, 3s. 6d.; Book 6, 3s. 6d.; Book 7, 3s. 6d.	

PUBLICATIONS OF THE SCIENCE MUSEUM (H.M.S.O.).

Davy, M. J. B.	*Aeronautics, Heavier-than Air Aircraft.* Part I. Historical Survey. (In the Press.) Part II. Descriptive Catalogue. (In the Press.)	G R n

Davy, M. J. B.	*Aeronautics, Lighter-than Air Craft*	G R m
White, E. W.	*British Fishing-Boats and Coastal Craft.* Part I. Historical Survey. (In the Press.) Part II. Descriptive Catalogue. (In Preparation.)	G R m
Barclay, G.	*Chemistry.* Part I. Historical Review, 1947. 2s.	G R m
Spratt, H. P.	*Marine Engineering.* Part II. Descriptive Catalogue. (In Preparation)	G R m
Forward, E. A.	*Mechanical Road Vehicles.* Part II. Descriptive Catalogue, 1948. 2s. 6d.	G R m
Spratt, H. P.	*Merchant Steamers and Motor Ships.* Part II. Descriptive Catalogue, 1949. 3s. 6d.	G R m
Westcott, G. F.	*Pumping Machinery.* Part I. Historical Notes, 1932. 2s. 6d.	G R m
O'Dea, W. T.	*Radio Communication, its History and Development.* (In the Press)	G R m
Forward, E. A.	*Railway Locomotives and Rolling Stock.* Part. 1. Historical Review, 1947. 3s. Part II. Descriptive Catalogue, 1948. 2s. 6d.	G R m
G. S. Laird Clowes	*Sailing Ships.* Part I. Historical Notes, 1947. 4s. Part II. Descriptive Catalogue, 1948. 3s. 6d.	G R m
Ward, F. A. B.	*Time Measurement.* Part I. Historical Review, 1947. 2s. Part II. Descriptive Catalogue. (In Preparation.)	G R m
G. Tilghman Richards	*Typewriters.* 1948. 1s. 6d.	G R m
Skinner, F. G.	*Weighing and Measuring.* Part I. 5000 B.C. to A.D. 500. (In Preparation.)	G R m
O'Dea, W. T.	*Darkness into Daylight.* 1948. 1s.	G R m
O'Dea, W. T.	*Electric Illumination.* 1947. 9d.	G R m

Astronomy

Baker, R. H.	*An Introduction to Astronomy.* 16s.	Macmillan G r m
Beet, E. A.	*A Guide to the Sky* 6s.	Cambridge G r m
Beet, E. A.	*Elementary Astronomy* 8s. 6d.	Cambridge G r m
Burns, P. F.	*First Steps in Astronomy* 6s. 6d.	Ginn G r m
Chant, C. A.	*Our Wonderful Universe* 7s. 6d.	Harrap G r m
Eddington, A. S.	*The Expanding Universe* 3s. 6d.	Cambridge G r a
Evans, D. S.	*Frontiers of Astronomy* 6s.	Sigma Books G r a
Gamar, G.	*The Birth and Death of the Sun* 18s.	Macmillan G r a
Hargreaves, F. J.	*The Size of the Universe* 1s. 6d.	Penguin G r m
Jeans, J. M.	*The Mysterious Universe* 3s. 6d.	Cambridge G r a
Jeans, J. M.	*The Stars in their Courses* 5s.	Cambridge G r m
Jeans, J. M.	*Through Space and Time* 8s. 6d.	Cambridge G r m
Jeans, J. M.	*The Universe Around Us* 15s.	Cambridge G r a
Jones, H. S.	*Astronomy in Daily Life* (Royal Institution Christmas Lectures, 1944-5). 12s. 6d.	Bell G r m
Jones, H. S.	*General Astronomy* 12s. 6d.	Arnold G r m
Jones, H. S.	*Worlds without End* 8s. 6d.	Eng. Univ. Press G r m
Jones, H. S.	*The Royal Observatory* 1s. 6d.	Longmans G r m
Jones, H. S.	*Life on other Worlds* 8s. 6d.	Eng. Univ. Press G r m

Lester, R. M.	*Practical Astronomy for the Forces* 2s. 6d.	Hutchinson	G r m
McHardie, G.	*Preparation of Mirrors for Astronomical Telescopes.* 3s. 6d.	Blackie	S R m
Smart, W. M.	*Astronomical Navigation* 5s.	Longmans	G r a
Smart, W. M.	*Astronomy Today* 7s. 6d.	Oxford	G r m
Smart, W. M.	*Foundations of Astronomy* 16s.	Longmans	G r a
Smart, W. M.	*The Sun, the Stars and the Universe* 12s. 6d.	Longmans	G R a
Spencer, L. G.	*An Illustrated Guide to the Stars* 1s.	Chambers	G R m
Thomas, O.	*The Heavens and the Universe* 7s. 6d.	Allen & Unwin	G r m

Biology

1. History and Biography

DeKruif, P.	*Microbe Hunters* 7s. 6d. (Pocket Books, Inc., N.Y., 1s. 9d.)	Cape	G r m
DeKruif, P.	*Men against Death* 12s. 6d.	Cape	G r m
Doorly, E.	*The Insect Man* 1s. 6d.	Penguin	G r m
Doorly, E.	*The Microbe Man* 1s. 6d.	Penguin	G r m
Gilmour, J.	*British Botanists* 5s.	Collins	G r m
Holmes, S. J.	*Louis Pasteur* 7s. 6d.	Chapman and Hall	G r m
Megroz, R. L.	*Ronald Ross, Discoverer and Creator.* 10s. 6d.	Allen and Unwin	G r m
Newman, G.	*The Rise of Preventative Medicine* 10s. 6d.	Oxford	G r m
Savory, T. H.	*Seven Biologists* 1s. 3d.	Oxford	G r m

Singer, G.	*The Circulation of the Blood* 2s. 6d.	Bell G r m
Singer, G.	*Greek Biology and Medicine* 3s. 6d.	Oxford G r m
Singer, C.	*A Short History of Medicine* 12s. 6d.	Oxford G r m
Truax, R.	*Joseph Lister: Father of Modern Surgery.* 10s. 6d.	Harrap G r m
Zinsser, H.	*Rats, Lice and History* 10s. 6d.	Routledge & Kegan Paul G r m
Locy, W. A.	*Biology and its Makers* 16s.	Henry Holt & Co. Inc. G r m
Locy, W. A.	*Growth of Biology* 16s.	Henry Holt & Co. Inc. G r m

2. General Biology

Abercrombie, M. and Johnson, M. L.	*New Biology.* (Issued at Intervals). 1s. 6d.	Penguin G r m
Bacharach, A. L.	*Science and Nutrition* 5s.	Watts Co. G r m
Carrel, A.	*Man the Unknown* 1s. 6d.	Penguin G r m
Dale, A.	*An Introduction to Social Biology* 15s.	Heinemann G r m
Darling, Fraser, F.	*Wild Life in Britain* 5s.	Collins G r m
Darling, Fraser F.	*The Natural History of the Highlands and Islands.* 21s.	Collins G r m
Edwin, M.	*Nature's Year* 8s. 6d.	Longmans G r m
Ennion, E. A. R.	*The Story of Migration* 10s. 6d.	Harrap
Fitter, R. S. R.	*London Natural History* 21s.	Collins
Ford, J. H.	*Chemical Control of Insects* 9s. 6d.	Pilot Press
Haldane, J. B. S.	*Possible Worlds and Other Essays* 3s. 6d.	Chatto & Windus

Harris, L.	*Vitamins in Theory & Practice*	8s. 6d.	Cambridge	
Hayward, J. A.	*The Romance of Medicine*	7s. 6d.	Routledge & Kegan Paul	
Henrici, A. T.	*The Biology of Bacteria*	17s. 6d.	Harrap	
Hill, A. V.	*Living Machinery*	7s. 6d.	Bell	
Huxley, J.	*Essays in Popular Science*	3s. 6d.	Chatto & Windus	
Huxley, J.	*Essays of a Biologist*	3s. 6d.	Chatto & Windus	
Keith, A. E.	*The Engines of the Human Body*	12s. 6d.	Williams & Norgate	
Knowles, F. G.	*Man and other living things*	10s. 6d.	Harrap	
Knowles, F. G.	*The Living Organism*	10s. 6d.	Harrap	
Nichol, H.	*Microbes by the Million*	1s. 6d.	Penguin	G r m
Perry, R.	*A Naturalist on Lindisfarne*	15s.	Lindsay Drummond	G r m
Perry, R.	*Lundy's Isle of Puffins*	6s.	Lindsay Drummond	G r m
Pirenne, M. H.	*Vision and the Eye*	9s. 6d.	Pilot Press	G r a
Pitt, F.	*Wild Animals of Britain*	12s. 6d.	Batsford	G r m
Plimmer, R.M.A. and V. G.	*Food, Health and Vitamins*	7s. 6d.	Longmans	G r m
Plimmer, V. G.	*Food Values at a Glance*	8s. 6d.	Longmans	G r m
Ridley, G. N.	*Man studies life*	2s. 6d.	Watts	G r m
Smith, B. W.	*The World in the Past*	15s.	Warne	G r m
Smith, K. M.	*Beyond the Microscope*	1s. 6d.	Penguin	G r m
Tansley, A. G.	*Our Heritage of Wild Nature*	8s. 6d.	Cambridge	G r m

Tansley, A. G.	*The British Islands and their vegetation.* 63s.	Cambridge G R a
Tansley, A. G.	*Britain's Green Mantle* 18s.	Allen & Unwin G R m
Thompson, J. A.	*Biology for Everyman* 2 vols. 25s. complete	Dent G R m
Turner, W. J. (Ed)	*Nature in Britain* 21s.	Collins G r m
Vesey-Fitzgerald, B.	*A Child's Biology* 8s. 6d.	Cassell G r s
Van Wyss, C.	*Living Creatures* 10s. 6d.	Black G r s
Wells, H. G., Huxley, J. and Wells, G. P.	*The Science of Life* 10s 6d.	Cassell G r m

3. General Botany

Keeble, F.	*Life of Plants* 7s. 6d.	Oxford G r m
Mangham, S.	*Earth's Green Mantle* 15s.	Eng. Univ. Press G r m
Ransom, F.	*British Herbs* 1s. 6d.	Penguin S R m
Rayner, M. C.	*Trees and Toadstools* 6s.	Faber S R m
Seward, A. C.	*Plant Life through the Ages* 30s.	Cambridge G r m
Small, J.	*Pocket Lens Plant Lore, Month by Month.* 5s.	Churchill S r s
Small, J.	*What Botany really means* 5s.	Allen & Unwin S r m
Turrill, W. B.	*British Plant Life* 21s.	Collins S r a
Brown, W. H.	*The Plant Kingdom* 25s.	Ginn S R a

4. Flowering Plants

Bentham, G. and Hooker, J. D.	*Handbook of the British Flora* 17s. 6d.	Reeve S R a

Blunt, W.	*Tulipomania* 2s. 6d.	King Penguin S R m
Bonnier, G.	*British Flora* 10s. 6d.	Dent S R m
Bonnier, G.	*Name this Flower* 10s. 6d.	Dent S R m
Brimble, L. J. F.	*Flowers in Britain* 15s.	Macmillan S r m
Brimble, L. J. F.	*Trees in Britain* 15s.	Macmillan S r m
Butcher, R. W. & Strudwick, F.	*Further Illustrations of the British Flora.* (1st Companion book to Bentham & Hooker's Flora). 17s. 6d.	Reeve S R a
Edlin, H. L.	*British Woodland Trees* 18s.	Batsford S R m
Fitch, W. H. and Smith, W. G.	*Illustrations of the British Flora.* (2nd Companion book to Bentham and Hooker's Flora). 17s. 6d.	Reeve S R a
Gilmour, J.	*Wild Flowers of the Chalk* 2s. 6d.	King Penguin S r m
Gilmour, J.	*Wild Flowers* 21s. (Not yet published)	Collins
Grigson, G.	*Wild Flowers in Britain* ("Britain in Pictures" Series). 5s.	Collins G r m
Grigson, G.	*Wild Flowers of the Meadow* 2s. 6d.	King Penguin S r m
Hayward, W. R.	*The Botanist's Pocket Book* 6s.	Bell S R a
Hodgson, N. B.	*Trees and Shrubs of British Isles* 9s. 6d.	Crowther S R s
Hodgson, N. B.	*Wild Flowers* 9s. 6d.	Crowther S R s
Hutchinson, J.	*British Flowering Plants* 25s.	Gawthorn S r a
Hutchinson, J.	*Common Wild Flowers* 2s.	Penguin S R m
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James, W. O. and Clapham, A. R.	*The Biology of Flowers* 8s. 6d.	Oxford S R a
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Scott, T. H. and Stokoe, W. J.	*Wild Flowers of the Wayside and Woodland.* (Wayside Pocket Guides). 10s.	Warne S R m
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5. Flowerless Plants

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Hubbard, C. E.	*British Wild Grasses* 1s. 6d.	Penguin	S r m
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Large, E. C.	*The Advance of the Fungi* 18s.	Cape	S R m
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Richards, P. W.	*Mosses* 2s. 6d.	King Penguin	S R m
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Mackinnon, D. L.	*The Animals' World* 7s. 6d.	Bell	G r m
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Richmond, W. K.	*Wild Animals in Britain* 5s.	Oxford	G r m
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Step, E.	*Animal Life of the British Isles* 12s. 6d.	Warne S R m
Wender, L.	*Animal Encyclopaedia* 12s. 6d.	Allen & Unwin S R m

7. Vertebrates

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Chrystal, R. N.	*Insects of the British Woodlands* 15s.	Warne S R m
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See also British Museum (Natural History) guides.

9. Aquatic Life

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Pencher, C.	*The Breeding of Farm Animals*	1s. 6d.	Penguin	G r m
Percival, J.	*Agricultural Botany*	18s.	Duckworth	G R m
Robinson, D. H.	*Good Grassland*	4s. 6d.	Eng. Univ. Press	G r m

Russell, E. J.	*British Farming* 5s.	Collins G r m
Russell, E. J.	*Lessons on Soil* 3s.	Cambridge G r m
Salisbury, E. J.	*The Living Garden* 6s.	Bell G r m
Street, A. G.	*Round the Year on the Farm* 3s. 6d.	Oxford G r m
Thomas, J. O. and Voysey, A.	*Farm and School* 8s. 6d.	Longmans G r s
Watson, J. A. S.	*The Farming Year* 4s. 6d.	Longmans G r s
	See also Young Farmers' Club Booklets. 1s. 6d. each	Evans Bros. G R m
	National Federation of Young Farmers' Clubs and Oxford University Press. *The Story of the Countryside.* Series. 2s. 6d. each	Oxford G r m
	See also publications of the Ministry of Agriculture and Fisheries	G R m

Chemistry

1. History and Biography

Chapman, S. (Ed.)	*Pioneers of Progress and Science* 2s. each.	S.P.C.K.
	Priestley	G r m
	Dalton	G r m
Doorly, E.	*The Radium Woman: Madam Curie.* 4s. 6d.	Heinemann G r m
Ellis, O. de C.	*A History of Fire and Flame* 15s.	Simpkin, Marshall
	An unusual book, full of queer facts and special information.	G r m
Ferchl, F. and Sussenguth, A.	*A Pictorial History of Chemistry* 25s.	Heinemann G r m
Findlay, A.	*A Hundred Years of Chemistry* 21s.	Duckworth G r m

Findlay, A.	*The Spirit of Chemistry* 10s. 6d.	Longmans G r m
Holmyard, E. J.	*Chemistry to the Time of Dalton* 3s. 6d.	Oxford G r s
Holmyard, E. J.	*Makers of Chemistry* 8s. 6d.	Oxford G r m
Lowry, T. M.	*Historical Introduction to Chemistry* 10s. 6d.	Macmillan G r m
Marsh, J. E.	*The Origins and Growth of Chemical Science.* 5s.	Murray G r m
Masson, J. I.	*Three Centuries of Chemical Science.* 10s. 6d.	Benn G r a
Nechaev, I.	*Chemical Elements* 8s. 6d.	Lindsay Drummond G r s
Partington, J. R.	*A Short History of Chemistry* 7s. 6d.	Macmillan G r s
Read, J.	*Humour and Humanism in Chemistry.* 21s.	Bell G r m
Read, J.	*Prelude to Chemistry* 16s. 6d.	Bell G r m
Taylor, F. S.	*A Century of British Chemistry* 1s. 6d.	Longmans G r m
Tilden, W.	*Chemical Discovery and Invention in the Twentieth Century.* 15s.	Routledge & Kegan Paul G r m
Tilden, W.	*Famous Chemists* 15s.	Routledge & Kegan Paul G r s

2. GENERAL

Allcott, A. and Bolton, H. S.	*Chemistry Today* 7s. 6d.	Oxford G r m
Kendall, J.	*Young Chemists and Great Discoveries.* (Royal Institution Christmas Lectures, 1938-9) 8s. 6d.	Bell G r s
Ellis, O. G. De G., and Kirby, W. A.	*Flame* 3s. 6d.	Methuen G r m
Williams, T. I.	*An Introduction to Chromatography* 10s.	Blackie S R a
Fowles, G.	*Lecture Experiment in Chemistry* 25s.	Bell S R m

Geology

Fearnsides, W. G. and Bulman, D. M. B.	*Geology in the Service of Man* 1s. 6d.	Penguin G R a
Holmes, A.	*Principles of Physical Geology* 30s.	Nelson G R a
Seward, A. C.	*Geology for Everyman* 10s. 6d.	Cambridge G r m
Stamp, L. Dudley	*Britain's Structure and Scenery* 16s.	Collins G R m
Swinnerton, H. H.	*Solving Earth's Mysteries* 8s. 6d.	Harrap G r s
Trueman, A. E.	*Geology and Scenery of England and Wales.* 1s. 6d.	Penguin G R m

Physics

1. History

Bryant, W. W.	*Galileo* 2s.	S.P.C.K. G r m
Evans, I. B. N.	*Rutherford of Nelson* 1s. 6d.	Penguin G r m
Faraday, M.	*Experimental Researches in Electricity and Magnetism.* 4s. 6d.	Dent G r m
Lemon, H. B.	*From Galileo to the Nuclear Age* 21s.	Cambridge G r m
McNicol, H.	*Seven Inventors* (Arkwright, Wedgwood, Goodyear, Wright Bros., Edison, Marconi). 1s. 3d. each	Oxford G r m
Oldham, T.	*Thomas Young, F.R.S.* 6s.	Arnold G r m
Randall, W. L.	*S. Z. de Ferranti* ("Science in Britain" Series) 1s. 6d.	Longmans G r m
Smiles, S.	*Lives of the Engineers* Vol. 1: Brindley, Vermuyden, Myddelton and Perry. Vol. 2: Smeaton and Rennie. Vol. 3: Metcalfe and Telford. Vol. 4: Boulton and Watt. Vol. 5: George and Robert Stephenson. 7s. 6d. each.	Murray G r m

Walton, J.	*Six Physicists* (Galileo, Newton, Davy, Faraday, Kelvin, Curie). 1s. 3d.	Oxford G r m
Wood, A.	*Joule and the Study of Energy.* 1s. 6d.	Bell G r m
Wood, A.	*The Cavendish Laboratory* 2s. 6d.	Cambridge G r m

2. General

Anniss, F.	*The New Practical Physics* Books I-VI. 2s. 6d. to 3s. 6d. per vol.	Gregg S R s
Avery, M.	*Household Physics* 24s.	Macmillan S R m
Gail, O. W.	*Romping through Physics* 5s.	Routledge & Kegan Paul S r s
Gamow, G.	*Mr. Tompkins in Wonderland,* or *Stories of c, g and h.* 8s. 6d.	Cambridge S r m
Gamow, G.	*One, two, three—Infinity* 24s.	Macmillan S r m
Jeffs, F.	*Fun with Physics* 4s. 6d.	Southern Editorial S r s
Richardson, E. G.	*Physical Science in Art and Industry.* 15s.	Eng. Univ. Press S r a
Richardson, E. G.	*Physical Science in Modern Life* 8s. 6d.	Eng. Univ. Press S r a
Ruhemann, M.	*Power* 6s.	Sigma Books S r m
Whetham, W. C. Dampier	*Matter and Change* 3s. 6d.	Cambridge S r m
Whitman, W. G.	*Household Physics* 19s. 6d.	Wiley S r m
Wittick, E. C.	*Development of Power* 5s.	Univ. Chicago Press S r m

3. Mechanics and Properties of Matter

Boys, C. V.	*Soap Bubbles* 5s.	S.P.C.K. S r m
Lawrence, A. S. C.	*Soap Films* 12s. 6d.	Bell S r m
McKay, H.	*Fun with Mechanics* 5s.	Oxford S r m

4. Light

Beck, C.	*The Microscope* 7s. 6d.	R. & J. Beck S R m
Bragg, W. H.	*The Universe of Light* 16s.	Bell S r m
Hartridge, H.	*Colours and How We see them.* (Royal Institution Christmas Lectures, 1946-7). 15s.	Bell G r m
Martin, L. C. and Johnson, B. K.	*Practical Microscopy* 6s. 6d.	Blackie S R m
McKay, H.	*The Tricks of Light and Colour* 5s.	Oxford G r m
Pirenne, M. H.	*Vision and the Eye* 12s. 6d.	Pilot Press S R a
Roberts, M. and Thomas, E. R.	*Newton and the Origin of Colours* 3s. 6d.	Bell S r *m*

5. Sound

Beatly, R. T.	*Hearing in Man and Animals* 5s.	Bell S r m
Bragg, W. H.	*The World of Sound* 7s. 6d.	Bell G r *m*
Dans, A. H.	*Noise* 2s. 6d.	Watts G r m

6. Magnetism and Electricity

Dance, H. E., Savage, E. G. and Ghey, G.	*Alternating Currents* (S.M.A.—Modern Science Memoir No. 21). 1s.	Murray S R m
Gibson, C. R.	*Modern Electricity* 6s.	Seeley Service S R m

Lee, J. A.	*The Grid* (S.M.A.—Modern Science Memoir No. 14). 1s.	Murray S R m
Lunt, J. R.	*Electricity for Everyman* 15s.	Macmillan G r m
Morgan, A.	*Getting acquainted with Electricity* 18s.	Appleton G r m
Morgan, A.	*The Pageant of Electricity* 16s.	Appleton G r m
Norris, R. C. (Ed.)	*Principles of Electricity* 8s. 6d.	Odhams Press G r m

7. RADIATION AND ATOMIC PHYSICS

Gamow, G.	*Mr. Tomkins explores the Atom* 10s. 6d.	Cambridge G r m
Solomon, A. K.	*Why smash Atoms?* 16s. Penguin 1s. 6d.	Oxford G r a

8. PRACTICAL PHYSICS

Shearcroft, W. F. F., and Avery, J. H.	*Practical Physics* 8s. 6d.	Heinemann S R m
Child, W. H. J.	*Physical Constants* 4s. 6d.	Methuen S R m

LABORATORIES

Adam, H. M. and Evan, J. H.	*Metalwork* 10s. 6d.	Arnold S R m
Adlam, G. H. J. (Ed.)	*The Science Masters' Book* 2 Series. Part 1 in each Physics. Part 2 in each Chemistry and Biology. 10s. each part.	Murray S R m
Ansley, A. J.	*An Introduction to Laboratory Technique.* 12s. 6d.	Macmillan S r m
Bagley, W. A.	*The Boys Book of Metalcraft* 3s. 6d.	Vawser & Wiles S R m

Bagley, W. A.	*Things to make and do* 3s. 6d.	Vawser & Wiles S R m
Bagley, W. A.	*Tin Can Craft* 3s. 6d.	Vawser & Wiles S R m
Barker, A. W. and Chapman	*Workshop Practice for Schools and Laboratories.* 3s. 6d.	Sidgwick & Jackson S R m
Duckworth, E. H. and Harries, R.	*The Laboratory Workshop* 10s.	Bell S R m
Ellis, P. E.	*An Introduction to Workshop Practice.* 5s. 6d.	Blackie S R m
Munby, H. E.	*Laboratories: Their Planning and Fittings.* 30s.	Bell S R m
Munby, H. E.	*School Laboratory Fittings* 7s. 6d.	Bell S R m
Nokes, M. C.	*Modern Glass Working and Laboratory Technique.* 7s. 6d.	Heinemann S R m
Parke-Winder, W. E.	*Simple Glass Blowing for Laboratories.* 6s.	Crosby Lockwood S R m
Pingriff, G. N.	*The Science Masters' Book* 3rd Series Part 1 Physics 10s.	Murray S R m
Woollat	*Laboratory Technique* 4s. 6d.	Longmans S R m
Science Masters' Association	*Safeguards in the Laboratory* 6d. Obtainable from the Librarian of the S.M.A.	Murray S R m
Joint Committee of S.M.A. and I.A.A.M.	*The Teaching of Science in Secondary Schools.* 8s. 6d.	Murray S R m

Periodicals

Bird Notes	Royal Society for the Protection of Birds, 82 Victoria Street, London, S.W.1. 1s. 6d. monthly.	S r m
British Science News	The British Council. 5s. per annum.	S r m

Discovery	Jarrolds (Norwich). Monthly 1s. 6d. or 19s. per annum.	S r m
Endeavour	I.C.I. 10s. quarterly.	S r m
Farming	Jarrolds. Monthly 1s. 6d. or 19s. per annum.	S r m
Meccano Magazine	Meccano Ltd., Binns Road, Liverpool, 13. 6d. monthly.	S r m
Model Engineer	Marshall. 9d. weekly.	S r m
Model Aircraft	Marshall. 1s. weekly.	S r m
Practical Mechanics	Newnes. 9d. weekly.	S r m
Railway Magazine	Railway Publishing Co. Ltd., 33 Tothill Street, London, S.W.1. Bi-monthly 2s.	S r m
School Nature Study	School Nature Study Union. 5s. per annum (quarterly issues).	S r m
Science News (Ed. Enogat, J.)	Penguin. 1s. 6d.	S r m
Science Today (Ed. A. W. Haslett)	Weekly News Letter, 104 Clifton Hill, London, N.W.8. 30s. per annum.	S r m
School Science Review The Science Masters' Association	Murray. 3 issues yearly, 14s. 6d. per annum.	S r m
Weather	The Royal Meteorological Society, 49 Cromwell Road, London, S.W.7. Monthly 1s. 6d.	S r m

Summary

A. General School Library.

1. Reference books.
2. Text-books.
3. Books for general reading.
4. Card-index system.

B. The Science Department Library.

1. Reference books.
2. Standard Text-books.
3. Practical Work Books.

CHAPTER TWELVE

VISUAL AIDS IN SCIENCE TEACHING

I propose to consider in turn, films, film-strips, lantern slides, charts, models, pictures, set pieces of apparatus, and the microprojector.

A. FILMS

Science films are roughly divided into two kinds: background films and direct teaching films. Background films are usually suitable for showing to fairly large groups of children because they do not deal with specific subjects. "Nagana"[1] is a good film of this type. In this film we are shown something of the ravages in central Africa of the disease nagana in cattle, which is transmitted by the tsetse fly. The wild animals have the trypanosome protozoa in their blood, but do not suffer from nagana. However, when a tsetse fly bites a wild animal it is likely to get some of these parasites in its blood which later mix with the saliva and when it bites a domestic cow it is very probable that some of the parasites will be injected during the biting into the animal. Domestic animals do suffer very severely from nagana. Various methods of counteracting the action of the flies have been tried and they are illustrated in the film. Finally we see methods of spraying the trees and undergrowth by D.D.T. from aeroplanes. The film is in colour and an atmosphere of Africaans is enhanced by the use of native music. This is a good background film on the subject of the social value of science. It can be shown with success to children from 11 upwards.

Lesson films should be shown as definite teaching aids in an actual lesson. A film of this type is the one on the Microscope[2]. In this film the technique of using a compound microscope is demonstrated very clearly. Every stage is dealt with in the focusing of a microscope and the illumination of the transparent object on the slide. If a teacher was introducing a class of 30 children to a microscope and how

to use one, this film would be a good start. Children in the last year at school should be capable of using a compound microscope, if they are reasonably intelligent. This film followed by a demonstration by the teacher would be a good combination of methods for teaching this rather skilled technique.

There are certain aspects of science which can be better illustrated by films than in any other way. I will mention a number of them.

Slow motion photography is sometimes used in films. This is accomplished by running a ciné-camera very quickly. A very special camera is used which accelerates quickly from zero and runs through 300 feet in a matter of seconds. It is a technique which is useful in a number of ways. We may wish to see what happens when a bullet pierces a sheet of glass. In a film of this kind you can see the sound wave travelling through the glass. It is useful for showing what happens to a piston at a high speed, how it actually changes shape during its movement. The same technique is employed in films of the movement of human limbs to show the correct strokes, say in the crawl, in swimming, or how to take a hurdle.

There is the opposite technique known as time-lapse photography. In this kind of photography the ciné-camera operates very slowly so that when the film is shown everything is speeded up. There is a particularly good film of this type called "The Dandelion".[3] In this film we see how a dandelion grows before our eyes. We also see, and this is most revealing, what happens when the top of a dandelion is cut off: more plants are produced from the decapitated stocks.

X-ray ciné photography is another technique. This is particularly useful in showing the movements of the internal organs of animals. By its means, films have been made to show the action of the arm, the movement of the heel, the swallowing of food, the pouring of a liquid into the stomach, the beating of the heart and the movement of the lungs. This technique can also be used for teaching about pathological cases, but this will hardly come into a Secondary Modern School course. A superb film of this type is "Bronchial Tree"[4] on the rabbit. The rabbit is caused to breathe a

gas which is opaque to X-rays. When the animal is photographed in the process of inspiring this gas you can, when viewing the finished film, observe how the gas enters the trachea, the bronchii and the alveoli in turn. You can also see the movement of the lungs and the beating of the heart. It is a first-class film of German origin.

There are also films incorporating ciné photomicrography. Using this technique there is a particularly good film showing the blood corpuscles in the capillaries of the rabbit's ear.[5] You can compare the shapes and sizes of white and red corpuscles. In this film you can see how the red corpuscles follow the movement of the general blood stream, whereas the white corpuscles can move of their own accord and can carry out scavenging operations in the neighbouring tissue. The same kind of technique has been used to show the flow of the sap in a plant. It is also used in films on crystallisation.

By a combination of photomicrography and X-ray techniques we can develop films of another type. For example, it is possible to have a film showing the action of the teeth in chewing. This would show the action of the teeth, their articulation and how they actually act on the food. Without X-rays it would be difficult to see what was happening.

Films can also be used to show the action of apparatus which is either too expensive for the school to buy or is inaccessible to the children for other reasons. This applies to apparatus used in Atomic Physics, such as the functions of the cyclotron or the atomic piles. It also applies to a number of other types of apparatus which the children could be led to understand by means of a good film. In films of this type the action of the apparatus can be made clear by the employment of good diagrams, moving where this is desirable. It might also be possible to show apparatus in sections. This will be found a useful type of science film.

Then again films can be used to show how certain laboratory skills can be carried out. These are not intended to be subsitutes for good teaching, but as aids to teaching. There is to be a film on microscope slide making.[6] When this film is shown, it should be followed up by demonstrations by the

teacher and practical work by the children. It might be possible to produce films on such subjects as glassblowing, dissection, titration and filtration.

Another type of film is the astronomical film. A good example of this type is one showing the corona of the sun.[7] Until recently, astronomers had to wait for an eclipse before they could photograph the corona and the various solar prominences associated with it. However, a certain inventive scientist thought of the idea of interposing a black circular disk in the sun's rays but in direct line with the axis of a telescope. When the astronomer looked through the telescope, with the requisite colour filters fitted, he was able to witness the corona just as well as if there had been an eclipse. This method has the advantage that you are not restricted by the times and places dictated by a total eclipse of the sun. A very fine film[7] of the sun has been made in this way. One of the prominences to be seen has a very striking resemblance to the explosion of an atomic bomb.

There are some films which use polarised light.[8] This one referred to was produced by the British Railways to show stresses and strains in a railway line when subjected to pressure by a train passing over it. The variation in colour in the chairs supporting the line may not have much significance for an audience composed of children of school age, but it can be pointed out that any change in colour of any part shows that the plane of that surface has altered relative to another surface.

Schools should be encouraged to maintain sea water aquaria. In support of the science learnt through carrying out this work, it is useful to show films about sea-shore life. There are too few films of this kind, though the subject is of fascinating interest. It would be nice if we could have one in colour.

The last type of film I desire to mention is that based on moving diagrams. Some of these have exceptional merit. The film "Elimination"[9] is entirely done by moving diagrams and the coloured film "Circulation"[10] is almost all in the form of moving diagrams. These are both first-class films of their type. Another film of this kind which made a deep

impression upon me was one showing the fractional distillation of oil. The molecules of oil were considered to consist of cards from a pack. Evidently the purpose of the fractionating column was to separate in turn the different suits: clubs, spades, diamonds, hearts. It was most interesting to watch the cards moving up and down the column and in and out of the trays.

The relative merits of sound and silent films are often discussed. What determines whether a film should be shown or not is its teaching quality not whether it is sound or silent. Most of the new films are sound films so that the only choices regarding these are either to take the commentary as it is, or to show a mute version in which the teacher puts in his own commentary, or (which is probably the best way) to show the sound film in its entirety and then partly mute. It is quite convenient to switch off the sound when you wish without any damage being sustained by film or machine. The great drawback from a classroom point of view in the sound film is that the projector is so heavy to move about from place to place. Another difficulty which occurs in schools is caused by the usually poor acoustics of classrooms.

B. Film Strips

These can be used in a number of ways. They can be used to supplement a film. A film on the manufacture of coal gas would for this purpose have a film strip which contained separate pictures of such items and processes as the retort (external, sectional and diagrammatic views); method of supplying coal; washing of coal gas; extraction of sulphur; extraction of ammonia; the gasholder and the gas meter at the gas works. Use could be made of external photographs, sectional photographs, diagrams and explanatory notes. Such a film strip would in its showing help to consolidate the knowledge obtained from the films on the production of gas.

A film strip can also be used to show various stages in a manufacturing process when a film is not available. There is a good film strip which shows the extraction of nickel from the ore. Each stage is shown clearly and descriptive text is

added where necessary.[11] We could do with more of these particularly for various processes of chemical manufacture.

Film strips are useful for showing different types of plants and animals. For example it should be possible to make one to illustrate the different kinds of animal life to be found in ponds. *Such a strip would be an aid to rough identification.* Other strips may be made of typical insects in the different orders; of typical flowering plants of the commoner families; of animals likely to be found on a rocky sea-shore; of tree leaves and of flower types. In the teaching associated with these subjects it would be necessary for the children to see actual specimens and also to collect them when engaged in nature study on rambles.

I should like to see one or two film strips on crystal structure: one of these would usefully deal with external crystal structure considering the seven styles of architecture. The second would deal with the modern interpretation of internal crystal structure using X-ray photographs and suitable diagrams. Some of the diagrams should explain the types of equipment used to obtain the X-ray photographs.

Another type of film strip might deal with chemical changes. This would be particularly suitable for a process involving a number of stages, where each stage could be illustrated in turn.

Yet another type of film strip could show processes of evolution. The subjects might range from the evolution of birds and reptiles from common ancestors to evolution based on man's improvement in skill such as utilisation of power, in which successive parts of the strip might show the progress from man power to electrical power. Another of this type could well deal with the improvement in lighting methods from torch light to fluorescent lighting.

It should be possible for the science teacher to make film strips[12] or if he cannot make such strips he could assemble the material and have the strip done professionally. Some education authorities help teachers in the making of film strips. It is not my purpose to explain how to make a film strip, but I have given references at the end of the chapter.[13]

C. Lantern Slides

Lantern slides are now made of two sizes, 3¼ in. by 3¼ in. and 2 in. by 2 in. There are advantages and disadvantages with either. The larger size is better for detailed reproduction, but on the other hand it is bulky. With the 2 in. by 2 in. you can obtain transparences of unbreakable material that clip together to make a slide.[13] Between the two transparent pieces you can place one 35 mm. ciné picture. This technique is very useful when pictures are taken with a camera using 35 mm. film. Dufay colour and Kodachrome are useful for this type of projection.

Lantern slides can be made of all kinds of objects and material. They have the advantage over the film strip in that the order of showing is entirely at the discretion of the teacher.

It is often desirable to show diagrams with a lantern. These can either be photographed and then printed on the lantern slide or else they can be drawn on the slide. The former method produces the better slide, but is more expensive. In the latter method, the operation can be carried out quickly and at very little cost. All you need to do is to give a clean slide a thin coating of Canada Balsam. This surface is then employed as a base for writing in Indian ink using a fine mapping pen. Indian ink of the waterproof variety can be obtained in different colours.

D. Charts

Charts can be either bought or made, but there is a surprising lack of good charts to purchase. A chart that is bought[14] should have bold lines and if coloured, the colours should differ sufficiently to be seen at the back of the classroom. There should not be too much detail obscuring the main points. Any labelling ought to be clear and in block letters. It is often an advantage to have charts which have no labels to obscure the actual diagram or picture.

There are certain advantages in making charts for teaching. You only need put in the charts what you wish the

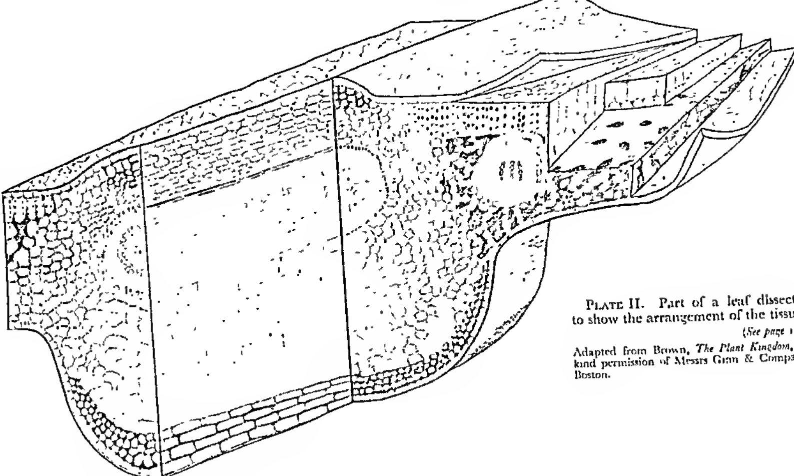
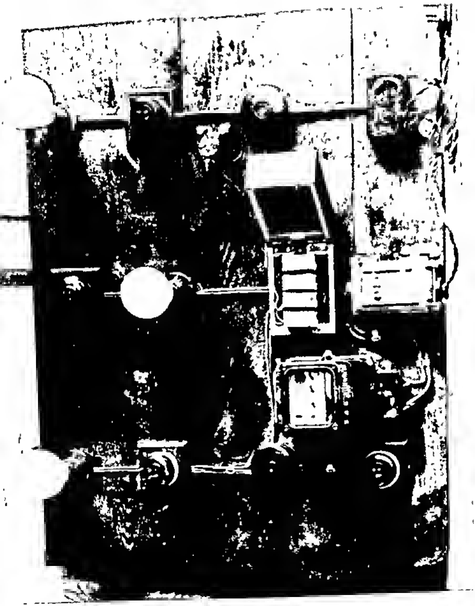


PLATE II. Part of a leaf dissected to show the arrangement of the tissues.

(*See page* 159)

Adapted from Brown, *The Plant Kingdom*, by kind permission of Messrs Ginn & Company, Boston.



children to notice. It is not necessary to make them elaborate; in fact it is usually a disadvantage. Simple direct charts are fairly quickly made and have a good appeal.

There is another type of chart which should be mentioned in connection with the science teaching. This is the chart which opens out to show the interior of something. It has been done for the human body, for the locomotive, for the motor car and for internal combustion engines of various kinds. Such a chart should be a supplement to the actual article where possible. In school this could not fully apply to some charts such as an anatomical one of the human body. In this case a good dissectable model would be useful.

E. Models

Models are used a great deal in science teaching. Those which are bought are usually expensive. Many models, particularly biological ones, are now made in new synthetic materials such as perspex. It is possible to buy many first-class models, but at a high price. There are ways of making models both temporary and permanent.[14] Such materials as plasticine, papier mâché, glass-rod and cellophane will be found most useful. By ingenuity teachers can make all kinds of models to help in their work. Some industrial firms will provide models of their equipment either on loan or as gifts. Many biological models can be loaned from museums.

F. Pictures

This subject has been considered in Chapter 5 fairly fully. Pictures are useful in teaching in various ways.

It is good to have pictures on the walls of the science room, but they should not be left there too long. However, good pictures may be, if they are left too long on the walls they become part of the wall and their educational value drops considerably. In addition to this, they get dirty.

I like to see a certain number of historical pictures placed on the walls of science rooms from time to time. Schools cannot imitate the Royal Institution by having actual apparatus

used by famous chemists. We can, however, provide good pictures of the great scientists and of some of the apparatus they used.

G. Set Pieces of Apparatus

This is a particularly important part of the services rendered by the science department. Set pieces of apparatus demand three things. There must be enough space to set them out. In many schools there is a great shortage of room, which really cramps the work of the school as a whole, including the work in science. There is often insufficient room for the storage of materials such as notebooks, textbooks, chemicals and general apparatus, so that the prospects of having set pieces of apparatus often seem remote. However, in new schools which are being built, the matter of set pieces of apparatus is being considered and room is being allowed. This is considered in the next chapter.

The second requirement is that of the teachers' skill, ingenuity and time. Without the teacher taking his full part there cannot be an adequate supply of fixed pieces of apparatus. He must be prepared to spend time out of the prescribed school hours in order to set up the types of apparatus I am about to describe.

The third requirement is that of materials. Not only must there be provision to buy materials from the usual laboratory suppliers, but there must also be a means of getting second-hand materials from junk stores and scrap yards. There is no limit to the ingenuity a teacher can show in getting the basic equipment to build up these set pieces of apparatus.

I will now make suggestions with regard to the types of apparatus which can be set up as visual aids. Other types of apparatus are considered in chapter 7. For the sake of convenience let me choose examples from the subjects Astronomy, Physics, Chemistry, Biology and Geology in turn.

In Astronomy, the obvious subjects which suggest themselves are a simple orrery and an apparatus for demonstrating eclipses of the sun and moon. An orrery to show the movement of the planets round the sun and the moon round the

earth can be made from scrap metal and wooden parts. The arrangements for moving these representational objects need not be accurate so long as they convey the ideas of planetary motion. Apparatus for showing eclipses is simpler in that you only deal with three representational objects, the sun, the earth and the moon. In this case you need a simple light source such as an electric lamp.

Physics occupies a much more important place in the curriculum than astronomy and consequently more set pieces of apparatus are demanded. I will suggest certain types and provide references where possible. Under the subject of heat we might have a model of the hot water system in a house (see drawing, fig. 25) and a sectional model of a coal mine to illustrate the principles of convection which are essential to maintain good ventilation. We might have a series of models to show different kinds of heat sources such as wood, coal, coal gas, electricity and of course, the sun.

Light can be illustrated by a piece of apparatus producing a rainbow, light-ray apparatus involving reflection at plane, convex and concave surfaces and refraction through water and different types of lenses; and a series of exhibits showing the evolution of lighting. This latter can be elaborated according to the room available. It should show such stages as the rush light, the candle, the oil lamp, the gas light, electric lighting and fluorescent lighting. There are all kinds of applications which might be included such as different forms of electric lighting in the home, stage-lighting, the making of an electric lamp, street lighting and industrial lighting.[14]

Sound suggests apparatus to denote nodes and internodes in tubes and along wires. It should be possible to set up some exhibits to show how musical instruments work.

Mechanics offers much scope for set pieces of apparatus. An old bicycle rear wheel with three-speed hub may be set up. It may be helpful to cut part of the hub away to show the action of the different gears. A motor cycle engine could be displayed with parts cut away to show sections. Various pulley systems can be set up to show their advantages. A

cycle pump could be arranged to show the amount of weight required to compress air by say one-half. A model water supply works would be of value to show methods of filtration and purification and to illustrate the law that water finds its own level. Pressures in a railway bridge could be illustrated in the way shown in the diagram (fig. 31). An illustration of

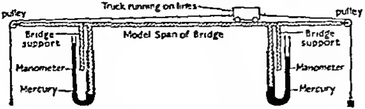


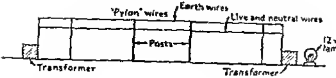
Fig. 31. Diagrammatic.

Bramah's press might be set up. Model steam engines with boilers would be of interest. If one could be of the horizontal type and another of the upright type and if one were driving a dynamo, these would be of very sound educational value.

Properties of matter could be illustrated in various ways. A machine may be constructed to illustrate the differences in the friction between such surfaces as glass and glass, steel and steel and oak and oak (smooth surfaces).

Magnetism and electricity offer a good deal of scope. A model of the household wiring system is a very popular model though to be realistic it should have a meter, fuses and plug sockets as well as lighting points. This can be run off the 12 volt A.C. supply. See photograph, Plate III, facing page 201. This model is intended to operate from the mains. A piece of apparatus to show why electricity is transported by high tension cables should be set up (see fig. 32). Apparatus can be fitted up to show how electric signs work, including how bell and indicator systems are fitted. Another type of set apparatus might illustrate the earth's magnetism. This could be done by having a magnet fitted in a geographical globe. On the outside of this could be fitted small compass needles.

A wireless set with all wiring and components visible may be fixed on the wall. Underneath the set should be a sheet of



paper with the wiring diagram. The wireless set should work effectively.

Chemistry does not offer quite the scope that Physics does. There may be examples of crystal structure; atomic models; a set of the products produced from coal. A complete unit on coal and its products would be of great interest. This should have a model gas works, a diagram of the working system and the products just mentioned. By comparison why not have a model of an oil refinery with a diagram and samples of its products?[17]

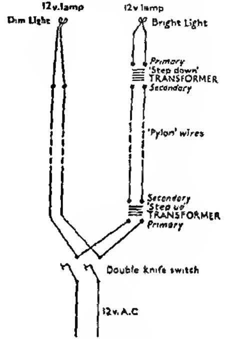


Fig. 32.

Biology has a great deal to offer in this line in the way of *plants and animals. A school should build up an herbarium* which can be consulted by ardent pupils. The plants should be correctly mounted[18] and arranged systematically. There should be a collection of insects[19] carefully set out. I place a great deal of importance on things being done properly in school; badly pressed plants and mutilated insects pinned in a haphazard manner have no educational value. The school will gradually accumulate specimens of other kinds such as sea-weeds, sea-shells, and mosses. Also as permanent

features, there should be aquaria of various kinds, including at least one sea-water aquarium[20] (see fig. 19). A tropical aquarium would also be of value. The latter should incorporate a thermostat.

Geology is a subject which is seldom included in the school curriculum. It has its value, but a close alliance with geography and a clinging to traditional subjects has tended to keep it out of schools as a science. This is a subject which offers some scope for section models of rock strata. A good model for the district in which the school happens to be is a useful permanent reminder of local geology.

H. Microprojector

This is a useful visual aid in the teaching of biology. Suggestions for the making of a microprojector are given in chapter seven, section B (1). With this apparatus not only can prepared slides be shown, but also small living specimens. It is a particularly useful piece of apparatus for illustrating pond life, though a microprojector which can be used in a vertical position (see fig. 33) is preferable for this

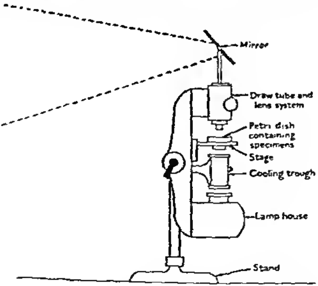


Fig. 33. Use of the Microprojector in a Vertical Position.

type of work. When the microprojector is in this position, the stage is horizontal and consequently watch glasses and Petri dishes containing pond life can be placed on it. This is found to be a very useful teaching aid.

The great advantage which a microprojector has over microscopes for most secondary modern school children is that with a microprojector used for projection you can point

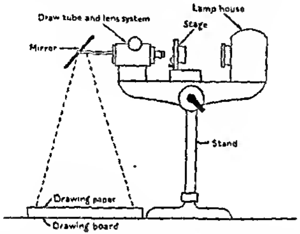


Fig. 34. Use of the Microprojector as an aid to Drawing.

out exactly what you want them to see. With microscope work it is by no means certain that the children see what you wish them to see. In addition, if the number of microscopes is limited to two or three as might well be the case, and you wish all the children to look at paramecia, there is likely to be much time wasted while the children are queuing to look through microscopes.

The microprojector can also be used for drawing purposes (see fig. 34). This is a great aid when an accurate drawing of say the transverse section of a buttercup root is desired.

In this chapter, I have indicated a number of visual aids which can be usefully employed in the teaching of science in the Secondary Modern School. The subject has been by no means exhausted, but I hope I have suggested useful methods and lines of development.

Summary

A. Films.
1. Background.
2. Lesson.
3. What can films do particularly well?

B. Film strips.

C. Lantern Slides.

D. Charts.

E. Models.

F. Pictures.

G. Set pieces of apparatus.

H. The Microprojector.

References (Chapter Twelve)

[1] Film: "Nagana". 16 mm. sound in colour, from South African Scientific Liaison Office, 39 Princes Gate, Exhibition Road, London, S.W.7. Free.

[2] Film: "The Microscope". 16 mm. sound. P.F.B. Free.

[3] Film: "The Dandelion". 16 mm. sound. G.B. Loan charge.

[4] Film: "The Bronchial Tree". 16 mm. silent. Available only through the Physiological Society, c/o Professor McDowall, King's College, London.

[5] Film: "The Microscopy of the Circulation". 16 mm. silent in colour. Available from Professor Florey, The University of Oxford.

[6] Film: "Microscope Slide Making". To be made by Realist Film Unit Ltd.

[7] Film showing the corona of the sun. 16 mm. silent. 10 mins. This film is the property of the Royal Astronomical Society and is loaned only to Fellows of that Society at the rate of 10s. per showing.

Film was made at the High Altitude Observatory of Harvard University under the direction of Professor H. F. Menzel. It shows the movements (much speeded up) of solar prominences with an explanatory title before each series of shots.

The film was taken through a coronagraph using a special narrow band pass polarising filter (this is a special filter developed and designed by Lyot for this particular work).

This film really needs showing by someone who knows something about it as no description or "explanation" of prominences is given and there are many other points which really need bringing out; for example to explain what the coronagraph is and why it was developed.

[8] Film using polarised light. 16 mm. silent in colour. British Railways.

[9] Film: "Elimination". 16 mm. sound. G.B. Loan charge.

[10] Film: "Circulation". 16 mm. sound (coloured). G.B. Loan charge.

[11] Film strip on Extraction of Nickel. Obtainable from Mond Nickel Co., Ltd., Grosvenor House, Park Lane, London, S.W.1.

[12] Falconer (V.M.). *Film Strips* (McGraw Hill).

Dodge and Thomson, *Film Strip do's and don'ts* (Carwal).

Hill, C. A., *Film Strip Projection* (Fountain Press).

Kidd and Long, *Film Strip and Slide Projection* (Pitman).

[13] Transparencies for clipping together to get 2 in. by 2 in. lantern slides made by Gnome. Obtainable from photographic dealers.

[14] W. & A. K. Johnston, Plant Biology Charts.

University of London Press, Biological Drawings.

G.B.I. Wall Charts (G.B. Equipments Ltd., Imperial House, 80-82 Regent Street, London, W.1): Sewage; World Fishing; The Turbo-Jet.

T. Gerrard & Co. Ltd., 46a & 48 Pentonville Road, London, N.1: Health and Sex Education Diagrams; Biological Blackboard Diagrams (Sidgwick & Jackson).

Flatters & Garnett Ltd., 309 Oxford Road, Manchester, 13: The "A.L." Educational Series on Elementary Physiology.

Macmillan: Practical Zoological Illustrations by Lockyer and Crofts.

[15] *Biological Models and Laboratory Apparatus*, by R. D. W. Brittain (John Murray).

Science Masters' Books (John Murray).

[16] Publications of the Science Museum, South Kensington. See book list, chapter 11.

[17] R. F. Goldstein, *The Petroleum Chemicals Industry* (E. & F. N. Spon, Ltd).

[18] *Science Masters' Book* (John Murray).
Preservation of Plants and Ferns (Routledge).
[19] See publications of Amateur Entomologists' Society, 167 Gunnersbury Park, London, W.5. See chapter 11.
Also C. D. Duncan & G. Pickwell, *The World of Insects*.
[20] See the author's article on "Marine Aquaria for Schools", *School Nature Study Journal*, No. 175, Vol. 44, April, 1949.

Scientific Film Catalogues

Association of Scientific Workers:
Graded List of Scientific Films. 1945. (Temple Fortune Press, Herbal Hill, London, E.C.1.)
Scientific Film Association:
Catalogue of Films of General Scientific Interest. (Aslib, 52 Bloomsbury Street, London, W.C.1.) 1946.
Films on Metals. (Aslib, 52 Bloomsbury Street, London, W.C.1.) 1949.

Abbreviations and Useful Addresses

B G C	British Gas Council, Gas Industry House, 1 Grosvenor Place, London, S.W.1.
B F I	British Film Institute, 4 Great Russell Street, London, W.C.1.
B I	British Instructional Films, 111 Wardour Street, London, W.1.
C C H E	Central Council for Health Education, Tavistock House, Tavistock Square, London, W.C.1.
C O I or C F L	Central Office of Information. Central Film Library, Government Building, Bromyard Avenue, London, W.3.

Crookes	The Crookes Laboratories, Gorst Road, Park Royal, London, N.W.10.
D H	*Dartington Hall Film Unit,* Totnes, Devon.
E G S	Educational and General Services, 1 Aintree Road, Perivale, Middlesex.
G B	Gaumont British Equipments, Mortimer House, 37-41 Mortimer Street, London, W.1.
I C I	Imperial Chemical Industries, Bolton House, Curzon Street, London, W.1.
I C I (Dyestuffs)	Imperial Chemical Industries (Dyestuffs), Hexagon House, Blackley, Manchester.
Ilse	Dr Dora Ilse, Physiology Department, The University, Birmingham.
Metrovick	Metropolitan Vickers, Trafford Park, Manchester.
Microchemical Club	Microchemical Club, c/o National Physical Laboratory, Teddington, Middlesex.

Mond	Mond Nickel Co. Ltd., Sunderland House, Curzon Street, London, W.1.
N F L	National Film Library, 4 Great Russell Street, London, W.1.
P F B	Petroleum Films Bureau, 29 New Bond Street, London, W.1.
Kodak	Kodak Ltd., 61 Kingsway, London, W.C.2. (not distributors)
Crossley	Crossley Brothers, Ltd., Openshaw, Manchester, 11.
D S I R	Department of Scientific and Industrial Research, Rex House, Lower Regent Street, London, S.W.1.
S C F L	Scottish Central Film Library, 16–17 Woodside Terrace, Charing Cross, Glasgow, C.3.
S F A	Scientific Film Association, 4 Great Russell Street, *London, W.C.1.*
Shell F U	Shell Film Unit, Shell-Mex House, Victoria Embankment, London, W.C.2.

W E A	Workers' Educational Association, 38a St George's Drive, London, S.W.1.
W F A	Workers' Film Association, 99 Leman Street, London, W.1.
W H	Wallace Heaton, 127 New Bond Street, London, W.1.

CHAPTER THIRTEEN

THE SCIENCE LABORATORY AND ITS EQUIPMENT

As with chapter 7, I would refer teachers to the book, *The Teaching of Science in Secondary Schools*, chapter 3 (John Murray) for much useful information on the subject of laboratories and their equipment. My purpose here is to consider special points as they apply to the Secondary Modern School, though first I wish to say something about the planning of laboratories in new schools.

On page 16 of the book just referred to, we are told, "In the ideal case the internal arrangements of science rooms would be designed first, and the walls subsequently arranged to suit them. Because this process is almost invariably reversed, and also because the men who will have to work in the laboratories are seldom consulted before plans are drawn, few really satisfactory science blocks exist". Now that some authorities are beginning to employ a Science Adviser on their staffs, this danger is, under these authorities, fast disappearing. He is experienced not only in science teaching, but also in laboratory planning. Where the Science Adviser works in close co-operation with the Architects, the best arrangements are made, for within reason he asks for what is required and these points are incorporated in the plan. The Science Adviser is usually better experienced in the matter of science laboratories than individual teachers for a number of reasons.

He sees many school laboratories and learns about their faults. He sees matters from different angles, whereas the science teacher is naturally biassed according to his own point of view. Such matters as the financial limit, the relation of the laboratories to the building plan of the whole school and the problems connected with labour and materials are often overlooked by the teacher concerned.

I wish to consider four types of science room problems. They will be dealt with in this order:

1. The old Secondary Modern School in which a classroom has to serve for Science.

2. The school in which there is a laboratory already in existence of an old type.

3. The new school with one laboratory.

4. The new school with two laboratories.

A. The Old Secondary Modern School in which a Classroom has to serve for Science

Teachers who work in the school and have to teach science in an ordinary classroom have a difficult problem, yet in many of them do good science. It is particularly important under such conditions that teachers should have a syllabus which can be carried out in spite of circumstances. A teacher faced with these conditions should as always make the best of it. What has the room to offer to help with the teaching of science? Is it the best room in the school for the purpose? If it is not the best room, then it is possible that the Head Teacher might be influenced to allow the best room to be used for science. This is where the help of the Science Adviser is useful. If even the best room is dark, can it be made any lighter? It may be possible to have additional windows put in or it may help if the walls are painted a lighter colour.

What about the work benches? The school may only have scholars' tables and chairs. In that case it is desirable to get portable benches 12 ft. by 3 ft. by 3 ft. high for the furnishing of the room. If you reckon four pupils to a bench that will work out at 8 benches for a class of 30 which should be an absolute maximum for a practical class in science (though personally I think 20 should be the maximum).

The next important point is the question of water supply It is, of course, desirable that a science room should have a water supply. At least one sink should be fitted with a laboratory water tap (ordinary taps of the household variety are unsuitable). The most desirable arrangement is to have fixed wall benches with sinks, about six to the room, each

with water taps. If one could have both hot and cold water that would be an advantage for washing apparatus.

Gas supply is also important. There should not only be two-way gas points on the side benches, but means whereby the portable benches can obtain a gas supply. This is best done from points on the floor with a flexible tube to a gas tube on the leg of the bench (see fig. 35). Details regarding portable benches will be given later. A two-way gas tap on each bench should be sufficient.

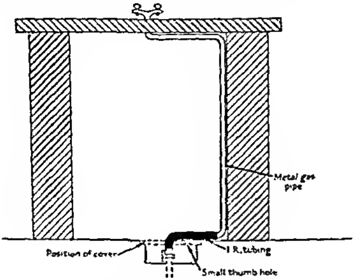


Fig. 35.

Electricity should also be available both as mains supply and low tension supply, though only low tension supply should usually be available for the children, except perhaps in the case of microscope lamps.

If a platform can be fixed for a teachers' demonstration bench that will be a considerable help, because when the teacher carries out a demonstration it should be visible clearly to all the children at the same time.

Behind the demonstration bench there ought to be a good blackboard, preferably one of the roller type. Boards and easels and other portable blackboards are out of place in a science room.

Another important matter is that of storage room. Very often the school which is so old fashioned as to have no science laboratory is also short of storage rooms, with the result that all the science equipment may have to be stored in the practical room itself. This is unfortunate, because it means that there have to be wall cupboards which not only take up floor space, but also wall space, which is so important in a science room.

Walls are useful not only for fixing wall benches and shelves to, but also for charts and certain experiments and pieces of apparatus. For example, experiments using pulleys can well be fixed on the wall. Fortin's barometer, the still, and a model wireless set should be fitted to walls. The more the walls are used, the more the other parts of the laboratory can be used.

Another useful piece of laboratory furniture is a mechanic's beam. This can conveniently be of this section ⌶ and should be fitted with holes at about 1 foot intervals to take strong hooks. From these hooks, pulley systems, a wheel and axle, and an apparatus for Young's modulus can be fitted. The beam should be about 8 ft. high so that it is clear of heads yet not too high for apparatus to be fitted. It can usefully extend the whole length of the science room.

In all laboratories there should be either waste boxes or bins with lids for solid matter such as filter papers, soiled marble, dissected frogs, remains of plants and so on. It is most important to train children not to put solid material down the drains—something which is easily done, especially after filtering or soil experiments or dissections of plants and animals. Because waste pipes are likely to get blocked up, it is desirable that stoppages should be easily dealt with. When the drainage system of a laboratory is designed, care should be taken that conduits can easily be examined.

B. The School in which there is Already in Existence a Laboratory of the Old Type

There are not many secondary modern schools of this type for two reasons. Either the Secondary Modern School is one

of the all-age schools which have been converted into a Secondary Modern School and did not possess a laboratory at all, or it is a new building altogether. The few exceptions are schools which were central schools and which under the Education Act 1944 have become Secondary Modern Schools. Most of these central schools had science laboratories.

In these laboratories the benches were usually fixed. In schools where there was both a physics and a chemistry laboratory you generally had the following types: The physics laboratory was the pleasanter room largely because it did not suffer from the deleterious effects of chemicals. In this room there were a number of fixed tables fitted with gas points. There would be one or two sinks in the room and, very rarely, low power electrical points fitted along the walls.

The chemistry laboratory would certainly contain fume cupboards, often inefficient. The benches would have shelves for reagent bottles and would have quite a large number of sinks, water taps and gas points. There would probably not be any low voltage electric points.

Quite often there would be a lecture room with long desks raised upon tiers, and in the better-built schools there would be preparation rooms and store rooms.

Teachers in buildiogs with these amenities are more fortunate than their colleagues in the schools without laboratories. With very little expense these rooms can be made serviceable for the modern teaching of science in Secondary Modern Schools. May I make the following suggestions?

The chemistry laboratory should become the biology and chemistry laboratory. Reagents should be removed from the benches so that all chemicals are in the direct control of the teacher. I do not recommend teaching much chemistry in the main course. As I indicated in chapter 2, there is a place for chemistry in the special courses if a school can offer them. Fume cupboards can be left because they are useful at times, but they should be made efficient. If necessary they can be fitted with an extractor fan. The large number of sinks and taps will be found most useful for the supply of water and the dispo[illegible]liquids in biology. If there are no side benches,

it would be well to have these fitted because they are very useful for aquaria, vivaria and long-term experiments such as those concerned with plant growth. The walls should be fitted with flat wooden rails for attaching charts. This room would appear to be the best room for the still since not only is there a good water supply, but there are adequate drainage points and also it is in this laboratory where most distilled water will be used.

There should be one or two good storage boxes so that large animals for dissection can be kept in formalin prior to and during use. These containers should be about 3 ft. by 3 ft. by 2 ft. deep, made of strong wood, lined with zinc, and fitted with a hinged wooden lid. The lid should have zinc on the underside to protect the wood from formaldehyde vapour. A zinc mesh tray should hook on to the sides so that specimens can easily be lowered into or lifted out of the container.[1]

The physics laboratory can under the new system still be used for physics. I would suggest that it is fitted with dark blinds which slide in grooves. These are quite efficient and if the windows open outwards, there can be adequate ventilation when the room is blacked-out. The room needs to be blacked-out for experiments on light and when using such visual aids as the epidiascope and film strip projector. If it is not convenient to provide dark blinds for the other laboratory, I would suggest that the microprojector is used in this physics laboratory.

Some windows have rather elaborate winding mechanisms for opening them. These present difficulties when providing black-out. With such windows it may be necessary to have curtains, though blinds would be preferable. In a laboratory there is always the danger with curtains that they will blow about and knock over pieces of apparatus. If necessary the elaborate opening mechanism for the windows should be taken off and a simpler system fitted (see fig. 36).

A low voltage supply should be fitted in this laboratory. Details of an efficient system are given later in this chapter.

This is the better laboratory of the two in which to fix a screen. The best position is usually by the blackboard. It

may be a screen supplied by a firm dealing in such things, or consist of a matt white surface on the wall by the side of the blackboard. For general use a matt white screen is better than either an aluminium one or a beaded screen. Although a beaded screen gives a brilliant picture it is very directional so that any children to the side of it will tend to see rather a dim image.

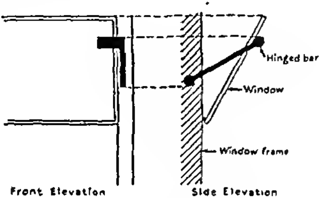


Fig. 36.

C. The New School with One Laboratory

Many new Secondary Modern Schools will have only one general purpose laboratory. This will have to serve for both theoretical and practical work. It will also have to serve for all aspects of the general science work. Whether any special science courses can also be run is rather doubtful under these conditions.

On pages 221 to 230 I have included scale drawings of a laboratory being incorporated in a school actually being built (figs. 37 to 46). It is worth some study. As a rule such laboratories are based on certain conclusions regarding the type of syllabus to be undertaken in such a school. A major consideration is that the subject matter will comprise physics and biology mainly with only a small amount of chemistry. In view of this there should be the following provisions made.

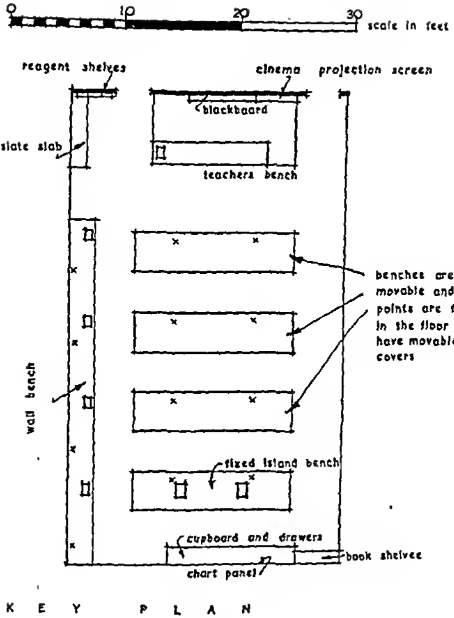

0
10
20
30
scale in feet
reagent shelves
cinema projection screen
blackboard
slate slab
teachers bench
benches are movable and gas points are fixed in the floor and have movable covers
wall bench
fixed island bench
cupboard and drawers
book shelves
chart panel
K E Y P L A N

Fig. 37.

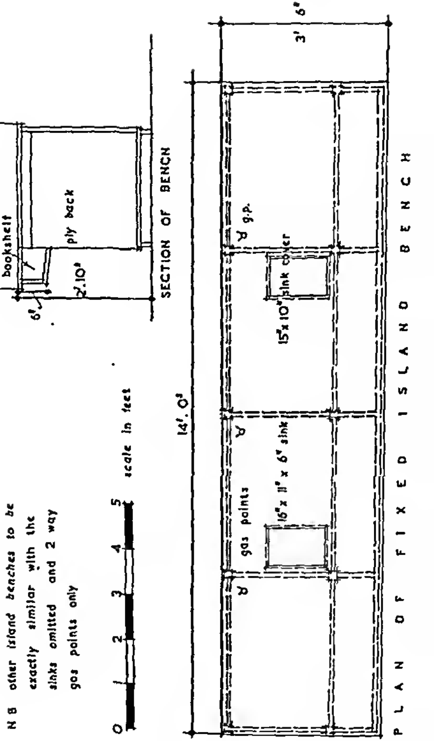
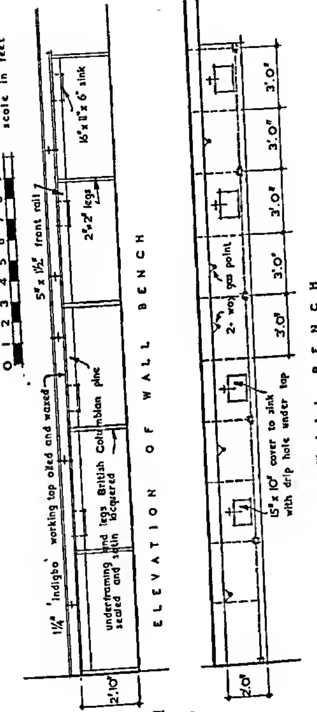

N B other island benches to be exactly similar with the sinks omitted and 2 way gas points only
scale in feet
0
1
2
3
4
5
SECTION OF BENCH
bookshelf
ply back
3' 6"
2.10"
6"
PLAN OF FIXED ISLAND BENCH
14' 0"
3' 6"
gas points
15" x 11" x 6" sink
15" x 10" sink cover
g.p.

Fig. 38.



scale in feet
0 1 2 3 4 5 6 7 8 9 10
16" x 11" x 6" sink
2" x 2" legs
5" x 1½" front rail
1¼" 'Indigbo' working top oiled and waxed
British Columbian pine
underframing and legs sealed and satin lacquered
ELEVATION OF WALL BENCH
2'.10"
3'.0"
3'.0"
3'.0"
3'.0"
3'.0"
2-way gas point
15" x 10" cover to sink with drip hole under tap
PLAN OF WALL BENCH
2'.0"

Fig. 39.

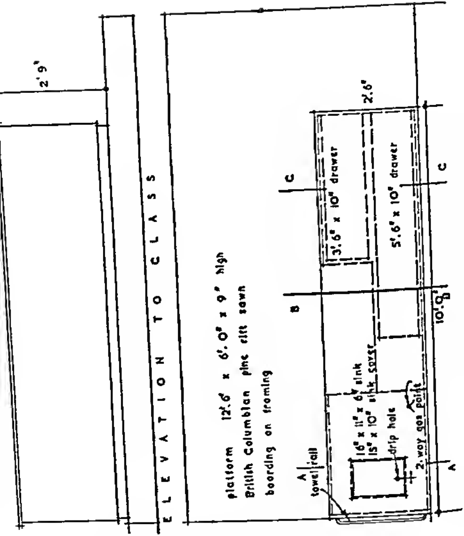


Fig. 40. Plan and Elevation of Teacher's Bench.

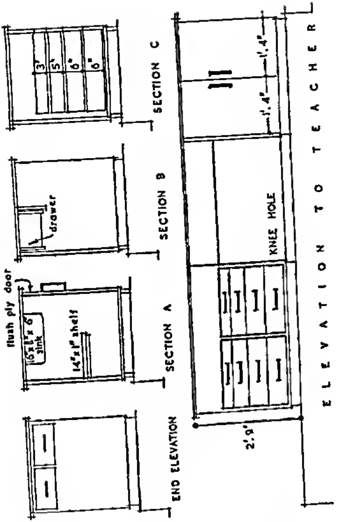


Fig. 41. Details of Teacher's Demonstration Bench.

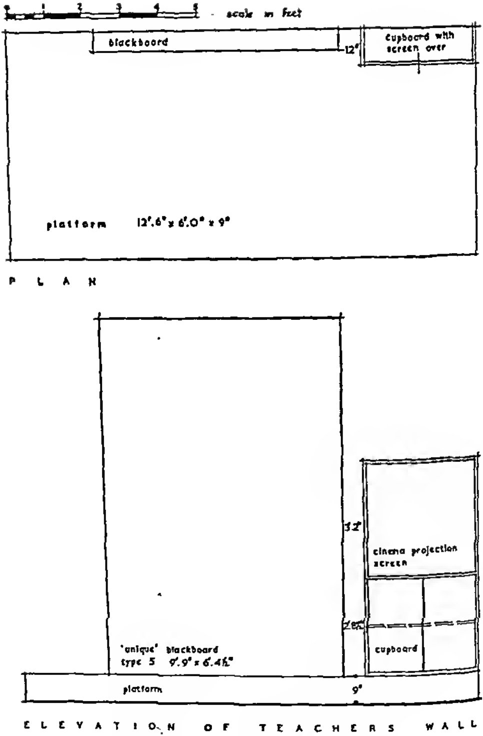


Fig. 42. Details of Teacher's Demonstration Bench.

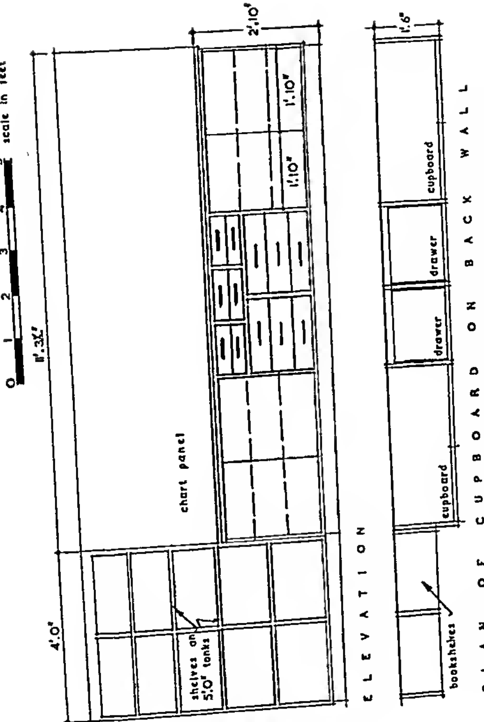
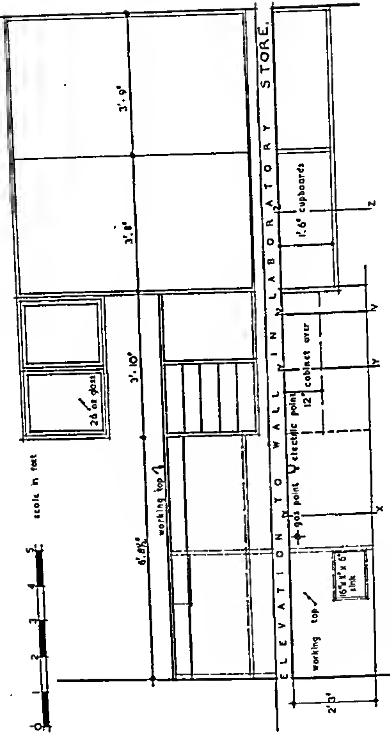
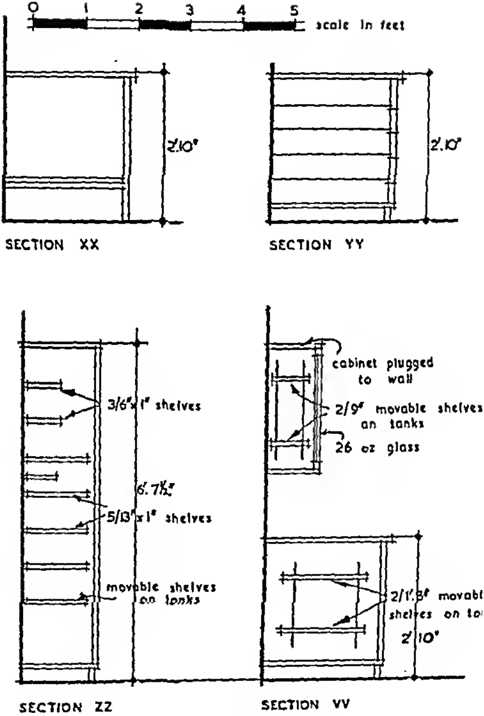

0 1 2 3 4 5 scale in feet
11'.3½"
4'.0"
2'.10"
1'.10"
1'.10"
1'.6"
chart panel
shelves on 5'.0" tanks
E L E V A T I O N
bookshelves
cupboard
drawer
drawer
cupboard
P L A N O F C U P B O A R D O N B A C K W A L L

Fig. 43.



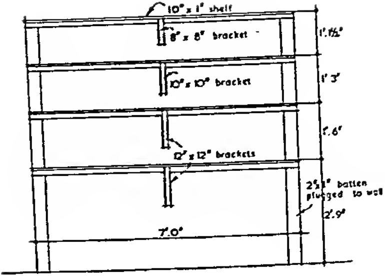
scale in feet
0 1 2 3 4 5
3'.9"
3'.6"
3'.10"
6'.8½"
26 oz glass
working top
ELEVATION TO WALL IN LABORATORY STORE.
1'.6" cupboards
cabinet over
12"
electric point
gas point
working top
16"x 11"x 6" sink
2'.3"
PLAN

Fig. 44.

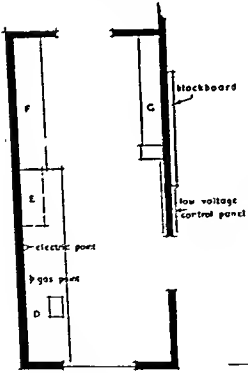


0 1 2 3 4 5 scale in feet
2'.10"
SECTION XX
2'.10"
SECTION YY
3/6"x1" shelves
6'.7½"
5/13"x1" shelves
movable shelves on tanks
SECTION ZZ
cabinet plugged to wall
2/9" movable shelves on tanks
26 oz glass
2/1'.8" movabl shelves on ta
2'.10"
SECTION VV

Fig. 45.

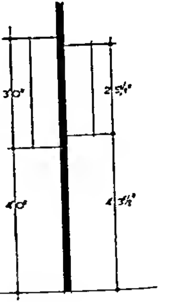


SHELVING G



KEY PLAN OF STORE
TO LABORATORY

0 1 2 3 4 5 scale in feet



L V CONTROL PANEL

0 1 2 3 scale in

Fig. 46.

The demonstration bench should be such that when the science teacher is carrying out an experiment, all the children in the class are able to see what he is doing. This means that not only must the bench be in a good position spatially, but also it should be well lit. There should be no windows behind the demonstration bench, because they tend to cause distraction. Overhead windows above the demonstration bench give good lighting, but may cause excessive heat and light in summer unless they can be covered with white blinds. There should be good electric lighting for the times when it is needed. Aluminium reflectors of the type shown in the drawing (fig. 47) have been found to be very efficient. They give not only direct lighting, but also indirect lighting from the ceiling, which should be white. The demonstration bench should be about 3 ft. wide and 18 ft. long and about 3 ft. high. It should have a polished teak top and be fitted with two 2-way gas points at the edge nearer to the class. If these can be controlled by taps under the lip of the bench near to the teacher so much the better. It is desirable to have a white acid resistant porcelain sink at one end of the bench (preferably the right hand) and this should have three water taps. It is useful to have a cold tap with an outlet high enough to get a Winchester bottle under it. There should also be another cold water tap that can have a metal water pump fitted to it and in addition a hot water tap. The hot water tap will be found very useful not only for washing apparatus, but also in a number of experiments where hot water is required.

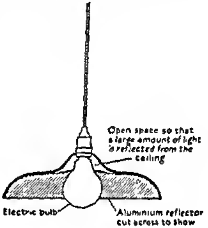


Fig. 47.

It is also useful to have a drainage point, which can be covered so as not to interfere with the general surface of the

bench, in the middle of the bench towards the front (i.e. the nearer part to the class).

At the left-hand end of the bench it is desirable to have electric power points, mains and low tension both D.C. and A.C.

Behind the demonstration bench should be fitted a blackboard, preferably a roller type or a folding type. By the side of the blackboard it will be useful to have a screen.

The minimum size of a science laboratory as laid down by the Ministry of Education is one having a floor space of 960 sq. feet. Like many minima of this kind, it tends to become a maximum.

Where a school only has one laboratory there is a great deal to be said for having movable benches in the centre and fixed benches at the sides. Gas can be supplied to the movable benches via gas taps in the floor in sunken recesses fitted with wooden covers. The connection to the bench can be to the nozzle at the end of the pipe on the side of the leg of the bench. This pipe in turn communicates with 2-way gas taps on the benches (see fig. 35.)

The side benches should have an adequate supply of sinks and taps, and of gas points. Low voltage supply both A.C. and D.C. can be supplied to the side fixed benches. There can also be an arrangement whereby the movable benches can be supplied with low voltage supply. This can either be done from the ceiling by means of flexible electric wires or from the floor plugs in recesses fitted with covers. Main electricity points may be fitted to the side benches, but they should be a safety type so that there is no danger of children getting electric shocks.

There should be adequate storage place for apparatus in general use. This can consist of cupboards and drawers under the benches and wall cupboards. Apparatus and materials not often used can be kept in the preparation room. If there are sets of apparatus in the cupboards and drawers in the benches for use of the children, such sets should be inspected frequently, at least once a month, to make sure they are kept in a serviceable condition and also to see that drawers and cupboards are kept tidy.

It is a convenience to have a supply of reagents on shelves in a cupboard behind the demonstration bench. This will be found to be very useful when demonstrations are carried out. It is desirable that no chemicals are kept on open shelves, particularly if the laboratory has to be used as a classroom.

Shelves can be fitted to the walls at about 7 ft. from the ground for demonstration apparatus as a temporary measure. The normal place for such is the store room, but there are many occasions when it is good for children to have more than one opportunity of seeing a piece of apparatus.

It should be possible to black out the room quickly, preferably by means of blinds in slots and it is also helpful if the laboratory lighting can be controlled by one switch near where the projector is likely to oe used. This makes it possible for the teacher to show say a picture from a film strip and then to switch on the lights so that the children can make notes or a drawing.

Fume cupboards are not usually necessary for general science unless it is desired to include a fair amount of work on the chemistry of metals. If there is no fume cupboard, it is desirable to have a hooded vent tube with an extractor fan in case the teacher wishes to demonstrate an experiment in which objectionable fumes are given off. This is seldom necessary in a secondary modern school science course.

Special fittings like the still, oven, Low Tension electricity supply and thermostat are considered later in the chapter.

D. The New School with Two Laboratories

A plan is given in fig. 48. These are details of an actual school to be erected. When there are two laboratories one can be used for physics and the other for biology. The general difference is that some of the benches in the physics laboratory are movable whereas those in the Biology laboratory are fixed. It is an advantage to have movable benches in the Physics laboratory because of the nature of apparatus used in such a place. For example, if it is possible to get hold of an old motor car engine and dismantle it, plenty of space is essential. Benches can be arranged in a circle and while some

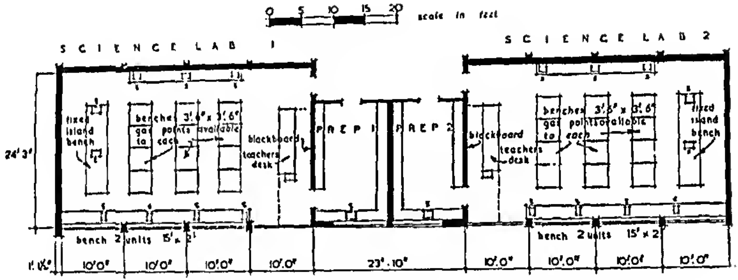

0 5 10 15 20 scale in feet
SCIENCE LAB 1
SCIENCE LAB 2
fixed island bench
benches 3'.6" x 3'.6"
gas points available
to each
blackboard
teachers desk
PREP 1
PREP 2
bench 2 units 15' x 2'
24' 3"
10'.0"
23'.10"

Fig. 48.

boys dismantle the engine in the centre, boys in the ring of benches can look at the parts. For some light ray experiments it may be found that one bench is too short, whereas two benches end-on meet the need very well. With pulley arrangements fitted to overhead girders, it is often desirable to have a good clear space. If a Foucault's pendulum is suspended from a girder, it is necessary to trace the path of the pendulum bob across lines on the floor.

The advantage of having fixed benches in the Biology laboratory is that these benches can be fitted with sinks which are very useful in such a laboratory. There is no need to have mobile benches in this type of laboratory.

Most other points regarding the differences between these two laboratories have been considered earlier in this chapter. It would be advantageous to have both rooms with windows fitted with blinds so that they can be blacked out when necessary. There will possibly be occasions when a demonstration with the microprojector is required in the biology laboratory at the same time that light experiments are being carried out in the physics laboratory.

E. Preparation and Storage Rooms

Ideally there should be a preparation and storage room for each laboratory. It is a pity to clutter up a preparation room with stored apparatus and chemicals. The preparation room as the name implies should be there for the purpose of getting experiments ready. Such a room should be fitted with a big sink (30 ins. by 18 ins.) with two taps for hot and cold water respectively and drainage pegs on a board. This may be the best place for a glassblowing bench and the corresponding equipment.

Such a room requires good bench space for setting up apparatus. Other real needs are big cupboards about 2 ft. deep with adjustable shelves. In these cupboards, set pieces of apparatus can be stored. The room should be well lighted both by windows and electric lights. It is also desirable to have plug sockets for mains current and Low Tension terminals.

Whether the wood- and metal-work benches are in here or in the laboratory will depend on circumstances. It should be remembered that the preparation room is essentially for the science teacher, whereas it is probably desirable that older children should have access to the wood-work and metal-work benches in the science department. Since this is so, it is probably best to have the benches in the laboratory, together with appropriate tools and materials.

The storage room should lead off from the preparation room. Normally it is kept locked. In this room should be stored all apparatus not in general use. Whereas set pieces of apparatus are stored in the preparation room, component items like beakers, flasks, corks, I.R. tubing, wire gauze, test tubes, specimen tubes, tripods, retort stands and so forth are kept in the storage room. These are surplus to the sets in the bench cupboards.

Chemicals should also be stored in this room. Strong open shelves are all right for this purpose provided the store room is kept locked. It is desirable that the shelves be such that they take only one row of bottles, but since the diameters of bottles vary so much it may be desirable either to have shelves becoming narrower from the floor upwards or to have sets of shelves of different widths. The former course may be the one to be adopted. Winchesters full of liquids or solids should always be kept on the lower shelves and it ought to be a firm rule that bottles containing concentrated acids and ammonia are kept on the bottom shelves near to the floor.

With regard to the storage of chemicals, it should also be a rule that no solids are kept in paper bags; they should either be kept in wide-mouthed bottles or in stoneware jars fitted with tight fitting stoneware lids. Care ought to be taken that deliquescent solids are kept in well-corked or glass-stoppered wide-necked bottles.

It is best to store glass tubing horizontally. Long shelves are desirable with vertical wooden or steel pillars at the front to prevent the glass tubing falling off. There should be trays of about 3 ft. by 2 ft. with ledges round the perimeters for the purpose of carrying apparatus to and from the laboratory.

It is desirable to store diagrams and charts flat in shallow

drawers. There should be some system of indexing so that a chart can be easily located.

The store room should be so arranged that things can be quickly found. At the end of each shelf with chemicals place a list giving the contents in order from left to right. Apparatus of the same type is best kept together, e.g. beakers, flasks, test tubes, Bunsen burners. It is desirable to have special parts of the store room for special apparatus appertaining to physics, e.g. lenses, light-ray apparatus, galvanometers, voltmeters, ammeters, wireless parts, calorimeters, magnets, sonometers and so on. There should be another section for biological apparatus such as aquaria, vivaria, dissecting instruments, biological models and specimens. Chemistry should also have its niche for special apparatus on flame, experiments on air, voltameters and so on.

F. Balance Room

There is not the same need for a balance room in a Secondary Modern School as there is in a Grammar School. The school will also be fortunate if it has a room available for this purpose. There are certain advantages in such a room. Not only can it be used for a balance room, but also for a room for quiet reading, and for housing the science class library.

Balances are always best kept out of laboratories unless they are for rough weighing. In the laboratories they tend to get dirty, and also the brass becomes corroded. Moreover balances should be free as far as possible from vibration. The table on which the balances rest can be protected from vibration by about four layers of corrugated paper under each leg.

Books can be arranged on shelves round the room. A few chairs and tables for reading are desirable.

G. Dark Room

There should be some arrangement for doing photography in the science department. A knowledge of photographic principles can well be part of the science course. In addition to this, children who are members of the Scientific Society

may wish to do some photography, some enlarging, developing and printing; the school ought to provide such facilities. The dark room is useful, for example, when the science teacher desires to do some photography for a film strip.

It is unlikely that a school will be able to have a room set apart for this purpose and no other. The most suitable room generally will be the preparation room, though it is often undesirable to have children working there because of having set pieces of apparatus about that are in the process of being made. When children are doing photography, it is usually necessary either to black out the laboratory, if this can be done effectively enough for photography, or to keep the preparation room so tidy that a few children can work in it without danger either to themselves or apparatus.

For dark room purposes, the room should have a safe light fixed on the wall above a bench. There should be an adequate supply of large photographic dishes and such appurtenances as forceps, a dish thermometer, stirring rods and a seconds illuminated clock. An enlarger is useful. This can be made in the school[2] and will greatly increase the value of the dark room. Photographic chemicals should be readily available. It is important that the science behind photographic work is fully explained to the children.

H. Greenhouse

If the school garden has a greenhouse, the facilities which such a place offers should not be overlooked by the science teacher. As I have indicated previously, there should be the closest collaboration between the science teacher and the rural science teacher. Just as the purpose of the school vegetable garden is not to produce vegetables for the school canteen, so the greenhouse is not primarily there to provide tomatoes. Like the rest of the school garden it is there for educational purposes. The greenhouse is very useful for experiments on plant growth. Much use can be made of it for experimental purposes. The heating systems of some school greenhouses are now electrically-controlled. With a greenhouse of this type some good scientific work can be done.

Modulat Oven type 2A, electrically heated and thermostatically controlled. Maximum temperature is 160° C.

The specification is as follows:

Design and construction.

Aluminium exterior 15½ in. wide by 14 in. deep by 20¾ in. high, finished heat and corrosion-resisting stoved cream enamel, of easy-clean modern design throughout.

Aluminium 12 in. cube interior with two perforated aluminium shelves 10¾ by 11¾ in. sliding on runners fixed to walls. Interspace at bottom lagged with glass wool. Adjustable, thermally insulated, ventilator provided at top, which acts also as thermometer support. Internal surfaces and shelves treated to protect surface from corrosion. Door of oven lagged with asbestos and fitted with a spring loaded catch.

Temperature control and heating.

Heating elements, total loading 650 watts, are of heavy gauge Nichrome tape, wound on mica-formers and operating at low wattage density, thereby ensuring long life. In the interspace the elements are secured to the bottom and two sides, and the invar-aluminium rod and bar thermostat to the back of the oven interior. The circuit is such that rapid heating is achieved, the maximum temperature of 160° C. being attained in one hour. The temperature control is by means of a slow motion drive with a circular scale angularly divided into 100 parts to cover the complete temperature range. The temperature control is such that at 160° C. an accuracy of ±2°C. is achieved as indicated by the thermometer. A rotary on/off switch and pilot lamp are provided, the latter connected to indicate the operation of the thermostat.

Complete with installation and servicing instructions and 1 yard 3-core cab-tyre cable, without thermometer.

For use on 200-250 volt A.C. only.

3. STILL

A suita[illegible] type of still for providing distilled water in chemistry[illegible] biology laboratories is one of the types made

by Manesty Machines Ltd., Speke Hall Road, Liverpool, 19.

The models the author suggests are either Destil Gas or Destil Electric. These models incorporate the following features:

1. Produce high quality distilled water at low cost.
2. Continuous in operation.
3. Supplied with a wall-mounting bracket.
4. Fitted with condenser tubes of heavily tinned brass.

The raw water enters at the bottom of the condenser, circulates round the heavily tinned condenser tubes and fills the boiling chamber to a height controlled by a specially designed weir. The steam condensing pre-heats the water almost to boiling point before it enters the boiling chamber, and dissolved gases are expelled to the atmosphere. Each model is fitted with efficient baffling to prevent entrainment of raw water in the vapour passing to the condenser.

The Destil Model will produce 2 pints of distilled water per hour. Other details of this model are:

Height	Net Weight	Gross Weight	Case Dimensions
21 in.	14 lb.	32 lb.	11 in. by 1 ft. 3 in. by 2 ft. 2 in.

A very important point about this type of still is that it does not take up any bench space being conveniently fixed on the wall.

4. Thermostatically Controlled Air Chamber

It is useful to have a thermostatically controlled air chamber for biological cultures. A fume cupboard, with the fume outlet closed, can be used for this purpose. The cupboard can be heated by gas or electricity with thermostatic control. This can usually be fixed up by the science master using for the control either an air thermometer or a bimetal strip.

Alternatively a thermostatically controlled water bath can be used to keep the cultures going (see fig. 20). The cultures can be kept in boiling tubes immersed in the water.

SUMMARY

A. The old Secondary Modern School in which a classroom has to serve for Science.

B. The school in which there is a laboratory already in existence of an old type.

C. The new school with one laboratory.

D. The new school with two laboratories.

E. Preparation and storage rooms.

F. Balance Room.

G. Dark Room.

H. Greenhouse.

I. Special pieces of Laboratory Equipment.
   1. Low-voltage installation.
   2. Oven.
   3. Still.
   4. Thermostatically controlled air chamber.

REFERENCES (CHAPTER THIRTEEN)

[1] T. Gerrard & Co. Ltd., 46a & 48 Pentonville Road, London N.1.

[2] See publications of the Focal Press.

[3] Sir Graham Savage and C. A. Belcher: Experimental Power Installation, *School Science Review*, Vol. XXX, No. 112, 1949.

APPENDICES

SCIENCE PROJECTS

1. THE BLACKBIRD (in outline) *page* 244

2. EARTH, FIRE, AIR AND WATER (in detail) 250

3. *UTILITY SERVICES: WATER, GAS, ELECTRICITY AND* WIRELESS (in outline) 260

4. BIOLOGY OF FOOD (in outline) 262

THE BLACKBIRD
(IN OUTLINE)

This project was carried out by three students at a teachers' training college. An outline of what was done is given. It is suggested that it can form the basis of "Bird Watching" with a few selected Secondary Modern School children. The author's view is that it is best for a school to concentrate on one type of bird for a time. To attempt to study several birds is ineffective and consequently useless. A good deal of useful research work can be done by the study of birds in the right way.

Here is a condensed account of the actual work carried out. Early researches, before the nesting season began and during the stage when the birds were pairing off, were made at Matson, Gloucester. Six nests were plotted here together with the approximate extents of territory and the "singing posts" of the cock birds. Note was also taken of the favourite stones on which the birds would crack open their snail shells. Owing to the robbing of the nests by small boys a fresh site had to be chosen. Eventually five nests in Brookthorpe were found.

Territory

The first point to be noted was a territory which each pair had selected. It was found in the case of the blackbirds in the Matson area that each bird's territory was apt to overlap considerably. An interesting thing about the territorial rights of these birds was that although they were usually observed close to the nests, some parts of the area were treated as communal feeding grounds although the feeding never took place closer than 12 feet.

Song

It was noticed that very little singing took place from the roost, and this was very desultory and did not develop into a real song until the singing perch was reached. Several

snatches of song were uttered during the actual flight from perch to roost. When the "singing post" was attained, the song lightened and deepened into that chant which is so familiar and which is often called the "morning song".

Singing took place on different occasions. Usually foraging for food was preceded by a song. Sometimes birds in adjacent territories were heard singing apparently in opposition.

The period of the year during which the blackbird sings appears to vary greatly with individuals. The peak period appears to be from the beginning of April to the end of June. The song varied considerably as the season progressed, getting almost harsh and unmusical towards the end. There is a definite difference in the song pattern of individuals.

Nests and Nesting Sites

The nests of blackbirds are found in various places as is indicated in the table below. The nesting season varies

Tables of Nesting Sites

Table 2

Area: Matson

Nests	*Site*	*Date building commenced* (1948)	*Date building finished* (1948)	*No. of eggs*
A	Quickset hedge	3 April	19 April	4
B	Quickset hedge	6 April	15 April (approx.)	4
C	Bramble and privet	14 March	30 March	3
D	*Ivy covered* trunk of tree	*16 April*	20 April	4
E	Quickset hedge	7 April	13 April	4
F	Low fork of elm tree	31 March	4 April	4

greatly with climatic conditions, a cold spell being sufficient to hold up the building that has already started, but normally the season lies between April and early June and the usual number of nests is two per season, although three nests have been recorded on rare occasions. Four to five eggs are laid, these being light blue with a heavy mottling of reddish brown spots.

The incubation period is usually fourteen days, the hen doing all the brooding. The young are in the nest for an average period of another fourteen days and both parents assist in the feeding.

Table 3

Area: Brookthorpe

Nest	*No. of Eggs*	*Site*	*No. hatched*	*Date hatched*
1	4	Low bushes	4	20 April
2	5	Quickset hedge	5	25 April
3	5	Quickset hedge	5	23 April
4	4	Pollard willow	4	29 April
5	4	Hedge bottom	4	26 April

Table 4

Area: Brookthorpe

Position	*Number of Nests*
Hedgerows and small bushes	24
Trees and tree trunks	13
Hedge bottoms and tree holes	8
Hole in the side of a wall	1
Broken down wheelbarrow	1
An old saucepan	1

Table 5

Area: Bushley

Position	*Number of Nests*
Hedgerows and small bushes	31
Pollard Willows	10
Other trees and tree trunks	5
Hedge bottoms and tree holes	9
Other sites (including a roll of barbed wire, a garden rose pergola and a bundle of bean sticks	6

Apart from the area which was being kept under close observation, 109 nests were recorded Of these, 26 nests were in gardens or very close to houses.

Observations were carried out on courtship, display and coition and also on domestication. Work on migration proved too difficult owing to the problems of ringing.

FEEDING

Some interesting observations were made on feeding. The tables which follow are based on half-hourly periods of watching.

Table 6

Area: Brookthorpe

Date	*Age of youngsters (days)*	*Time of watch (hours)*	*Total No. of feeds*	*No. of feeds by cock*	*No. of feeds by hen*
24/4/48	2	1	18	12	6
1/5/48	8	½	12	7	5
2/5/48	9	1	26	14	12
8/5/48	15	½	8	3	5
9/5/48	16	1	14	6	8

It was noticed that on the 5th May, 1948, the youngsters had left the nest but were remaining in the same hedge.

Table 7

Date: Saturday, 24th April, 1948. Age of youngsters: 1 day.
Nest No. 3 Brookthorpe

Time	*Bird feeding*	*Food*	*Other remarks*
p.m.			
3.10	cock	insects	Hen brooding. Cock fed hen and then fed youngsters.
3.12	cock	insects	Hen brooding. Cock fed hen and then fed youngsters.
3.13	cock	insects	Hen had left nest.
3.15	hen	insects	Hen then recommenced brooding.
3.18	cock	insects	Cock fed both hen and chicks.
3.25	cock	insects	Food given to hen.
3.37	hen	insects	Only one chick asked for food. Hen fed this one and continued to brood.
3.42	cock	insects	Both hen and youngsters fed.

Table 8

Area: Bushley

Date	*Age of youngsters (days)*	*Time of watch*	*Total No. of feeds*	*No. of feeds by cock*	*No. of feeds by hen*
25/4/48	3 (approx.)	½ hr. a.m.	8	6	2
25/4/48	3 (approx.)	½ hr. p.m.	9	5	4
2/5/48	10 (approx.)	½ hr. a.m.	14	8	6
2/5/48	10 (approx.)	½ hr. p.m.	15	7	8
9/5/48	The youngsters had left the nest and could not be found.				

The interesting points to notice about the preceding tables are:

(1) During the early days a "little food and often" was the rule and the cock had to do most of the feeding as the hen was brooding the youngsters.

(2) After the first week, much more food was being given to the youngsters. They were growing rapidly and commencing to quill heavily. Both parents were able to bear equal shares in this feeding as the young did not require so much brooding.

(3) After the youngsters were fledged, the parents were not so assiduous in their feeding. They were both concerned with going to nest again and probably the youngsters would pick up food for themselves much more quickly by reason of their being partially ignored.

APPENDIX TWO

A PROJECT ON EARTH, FIRE, AIR AND WATER

1. The Development of the Conception of an Element

Plato's four elements were what we might now term the elemental bases of the material world. There is the earth on which we walk; on which we grow our plants and feed our domestic animals; from which we extract coal, oil and metallic ores; and from which we obtain clay, sand, lime and other materials utilised in the construction of our cities. Secondly there is fire, about which there has always been something of a mystery. Savages worshipped it because it appeared untameable and ruthless in its powers of destruction. Evidence of its purifying nature is suggested in the practice in the past of cauterising wounds and in the present practice of cremation.

The third element was the air. This again is a very significant substance in the material make-up of the life we know. Considered quite simply, the air is the atmosphere in which we and our domestic creatures live.

Finally there is water. This was the medium in which all life used to exist. It is only comparatively recently in Geological time that creatures took to the land and consequently to breathing air.

From Plato's elemental conception of the place in which we live, we can trace briefly the development of man's understanding of the nature of matter. We can show how he came to analyse the world and find that it was made up of some 93 elements, only 20 of which were common. It was John Dalton of Manchester who first worked out the nature of the elements. From his work we can trace the development of Atomic Physics and arrive at our present ideas of matter. It should be possible to give the children in their last year a simple conception of the atom with its nucleus and its periphery of electrons.

2. The Earth

The second stage in the development of this theme concerns the first element of Plato: the earth. This might begin with some simple geology showing how the layers of rock were produced in the past. It can be shown how rocks break down to form soil and how the nature of a soil is to a large degree controlled by the underlying rock structure.

This leads on quite naturally to the composition of the soil. Such important components as clay, sand, humus, lime, and metallic salts might be considered. Children should have an opportunity to carry out simple experiments on the composition and nature of the soil. The composition experiments should include methods for finding the varying quantities of the different kinds of soil water, e.g. available water, capillary water and hygroscopic water. Methods of investigating the presence of a carbonate, metallic radicles and the *p*H value should be given.

The next subject is that of a plant's soil requirements. Although the soil may have all the materials which a plant requires, unless these materials are available to the plant, they are useless so far as the plant is concerned. Here we might demonstrate how we extract available substances from the soil (see fig. 3).

From this there might follow a consideration of the modern methods of treating soil by means of organic and inorganic manures. Basically soil is treated so that it will contain the substances required by the particular crops which are to be grown on it. Plants have different requirements; it is part of the business of the scientist to discover what these are.

Some thought might also be given to the inhabitants of the soil both plant and animal. It is part of the work of the cultivator to encourage those inhabitants which improve the soil, particularly the bacteria concerned with making nitrogen available to the plant, and discouraging those inhabitants which have a bad effect on plants such as anaerobic bacteria, fungi, weeds and arthropod pests of various kinds. Methods of soil sterilization can be dealt with.

Before completing our study of the earth we should draw the attention of the children to the important raw materials

which we obtain from the earth. In particular, mention should be made of coal, oil, metallic ores, sulphur, clay, sand, and limestone. This is a subject which could well form the basis of a long science course. It does provide an excellent opportunity to introduce chemistry in its proper place.

3. Fire

The subject of fire can begin with early ideas about combustion. As we might expect, early ideas as to what happens when iron rusts were rather vague. It is important to remember that vagueness has not disappeared even from scientific work. Whilst science aims at clarifying problems, this clarification is progressive and often slow and there are still many unsolved problems. In fact the solution of one problem often leads to another problem which may be just as shrouded in mystery as early ideas on combustion.

The Phlogiston Theory can form the subject of a number of lessons bringing out the historical development of that branch of chemistry concerned with oxidation and reduction and the commoner gases. The fact that Priestley believed in Phlogiston all his life does show that it is possible for an outstanding scientist to be misled. An interesting point in the overthrow of this unsound theory was the way in which quantitative experiment disproved the Phlogiston theory beyond doubt. When Lavoisier carried out his famons experiment of heating mercury and weighing it before and after thus showing that it gained in weight he proved that when a metal was heated and gained weight, it must gain material substance. It could not lose material substances as the Phlogistonists suggested. The Phlogistonists really went wrong because they regarded fire as a material substance, for they said that when a material was heated it lost the fire element. The fact that they did not weigh the metal before and after the experiment was an error of method.

The next topic included in the subject of Fire, is that of Heat and Energy. Mechanical and Heat Energy are probably the most obvious forms of energy to a child. There is evident energy when a nail is hit by a hammer or a fire burns with shooting flames and crackling sounds in the hearth.

We can show here, how one kind of energy can be transferred into another, but with loss of useful energy. When the hammer hits the nail some of the energy is utilised in driving the nail into the wood, but some is lost as heat energy, for the nail gets hot. The fire in the grate gives out heat, but it also gives out light and sound which have no heating value.

We can next consider flame. It is interesting to trace the control of flame by man. To the savage the fire at first appeared uncontrollable until he learned how to use the fire first to ward off prowling animals from his cave and then by cooking his food. The use of flame and the heat from the flame has evolved from this through such stages as the fire on the floor in the centre of a room; the big Tudor fireplace; Rumford's stove; modern coal fireplaces and finally electric wall bars and central heating. There has been a parallel evolution in laboratories and industry.

It is interesting to compare drawings and pictures of laboratories and workshops of different ages. The cumbersome pieces of equipment, such as coke stoves, are very evident in the pictures of the laboratories of the early 19th century. In fact the general difference in the equipment both of laboratories and workshops of the 19th century from those of the present is that unwieldy and often untidy machines and apparatus have given place to articles which are distinctly functional.

Any work on flame should include a study of the candle flame and the Bunsen burner. The Bunsen burner leads on to a study of explosion waves. A useful piece of apparatus of this kind is illustrated in fig. 49. By varying the properties of air and coal gas and the time lapse in sparking after turning off the gas, it is possible to demonstrate different types of explosion waves.

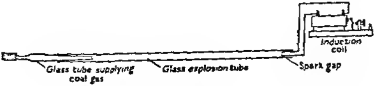


Fig. 49.

The incandescent gas mantle can then be considered. This made a big improvement, which was effective not only for gas lighting, but also for oil lighting. The work of Welsbach on the use of thorium oxides was a great contribution towards the advancement of illumination.

From here we can follow a different line in regard to flame. We can consider the fiery origin of the earth in the sun. The various theories which attempt to explain the earth's origin can be considered on their merits. The sun itself is a subject of great appeal especially to boys. Such matters as consideration of the energy relations of the sun and earth; comparison of the composition of the sun with that of the earth; a study of the various prominences; and the energy output of the sun itself, are all full of interest.

The subject of Fire should not be dismissed until we have considered the transfer of power. Human power after thousands of years was replaced by animal power and then by water power. It was a long time before the power of the flame was harnessed to do work for man. The early Greek attempt of Hero was not taken up until Watt worked out the principles of the steam engine. Watt's invention really made the Industrial Revolution possible. Industry moved quickly afterwards because a great supply of energy which could be harnessed had been found. In principle a steam engine is a device whereby some of the heat of a flame causes water to boil and produce steam. We can consider that some of the energy from the flame is locked up in the steam which is later turned into useful mechanical power by moving a piston backwards and forwards in a cylinder. This in turn drives a fly-wheel which makes continuous motion possible.

This section on Fire might well end by work on electricity since electricity is largely produced on the large scale by carrying this matter of the transfer of power a stage further. The steam engine is now made to drive a dynamo which generates electricity.

4. The Air

The discovery that air was a mixture, begun by Cavendish Priestley and Lavoisier, and the complete elucidation of this

mixture by Ramsay, Rayleigh, and Travers make good scientific history. After considering air as an element it was difficult to accept the idea of its being a mixture. Hooke suspected that it was a mixture of two gases but he was not able to prove it. When children carry out such experiments as burning a candle under a bell jar in a pneumatic trough containing water they are repeating experiments of great historical significance. This is often not stressed sufficiently.

Work of this kind leads on quite naturally to showing that air is a mixture, and to discovering the constituents of this mixture and their proportions. Consideration of air as a mixture provides a suitable contrast to water as a compound which follows in the next section.

In the elucidation of the constituents of air, we have an opportunity to show how scientific research works. Here we can witness how the progress of the investigation throughout the years, and the improvement in research methods and apparatus, at last enabled Ramsay and his colleagues to isolate and obtain the important physical constants of the active gases. This account of the determination of the composition of air is well worth recounting. It should so far as is practicable be illustrated by experiments.

The subject of the air should not be dismissed without dealing with the individual gases. There is oxygen which is necessary for the breathing of most plants and all animals, which is necessary for combustion, and which is necessary for decay.

Nitrogen is often dismissed too lightly, by considering it merely as diluting the oxygen. There is the part which it plays in the nitrogen cycle, by which we see how it is made available to plants. Nitrogen is a most important element in the structure of proteins which play so essential a part in the building of plant and animal structures. Although carbon is the universal element in plants and animals, it would seem that nitrogen is brought in to build up those compounds which are intrinsically linked up with the essential business of living.

Water vapour is particularly important because of its insulating properties in providing an atmospheric blanket

which prevents the too rapid loss of heat from the earth into space. It also tends to modify the intensity of the sun's rays.

Carbon dioxide is most important in regard to the carbon cycle. It is desirable to compare both the nitrogen and carbon cycles to see how they link together. In dealing with carbon dioxide, special consideration should be given to the photosynthesis or carbon assimilation as some people call it. Photosynthesis is a remarkable process by which carbon from the carbon dioxide of the air is built up first into monosaccharides; then into disaccharides and later into polysaccharides such as starch and cellulose. Later in the processes, the carbohydrates take part in combinations with nitrogen compounds to build up proteins.

The commercial uses of the inactive gases can be briefly mentioned. It is also important to show how helium is a by-product in the atomic fission of uranium, and niton is an emanation from radium.

5. Water

The fourth and last 'element' of Plato can now be considered. The early work on the composition of water was worked out by Cavendish by performing the synthesis of water and measuring its composition. Cavendish's proof of the compound nature of water was weakened because he expressed it in terms of the phlogiston theory. The investigation of the nature of water is therefore linked up with Fire and Combustion.

The peculiar behaviour of water in the manner in which its density alters is important. Ice is lighter than water, but then the density of liquid water rises as water at 0° C. it heated, reaches a maximum at 4° C., and then falls until as 100° C. the water boils. These two factors account for the important fact that ice forms on the surface of a lake first. Because of this and because of the insulating effect of ice; deep lakes never freeze completely. In fact even in arctic and antarctic waters, the ice is not very thick in comparison with the depth of water. These facts have important bearings on our way of life. We can draw water from reservoirs in the coldest part of the winter and the population of inland

waters and the sea is not seriously affected by the formation of ice on their surfaces.

Water should be considered in its great role as a transporting medium. Harvey was quick to see this in the circulation of blood in the human body. The circulation of blood and its pumping in the body are copied in many of man's inventions. There are the inland waterways; the sewerage system; the use of hydraulic pressures; suction pumps and force pumps and, of course, the transportation of water for domestic and industrial uses. The subject has many ramifications and a selection of these would have to be made in a course devoted to this topic.

Faraday and electrolysis may next be considered. The electrolysis of water is a convenient way of showing a method of finding the composition of water. It also shows how electricity is often linked up with chemical reaction.

An important and fascinating field of work is the place of water in plant and animal relations. Possibly the most important landmark in evolution is the change from aquatic to terrestrial life. The way in which both plants and animals adapted themselves to an existence on land is most interesting. Let me just mention one aspect. Water has a more buoyant nature than air, consequently a plant or animal will receive more support in the water than it will in the air. It is true that a land animal or plant receives support from its basal resting on or attachment to the land, but the air which surrounds it on land has not so buoyant an effect as water. This difference meant that a fundamental change must follow the transition from water to land if the plants and animals were to survive.

Floating plants have thin and tenuous stems. Such a form is unsuitable for a terrestrial existence unless a plant can climb other plants of which we have evidence in the lianas and other creeping plants. For this state of affairs, it is essential that some plants shall develop strong stems which will enable them to stand more or less vertically. This, indeed, as we know, has happened.

The water is able to support large animals with or without legs; the legs in fact are hardly necessary. Today we find that

the largest mammal is the whale which is supported by salt water. When an animal takes to the land it must either crawl so that its body is entirely supported by the land or else it must develop strong legs to support its body. There is an efficiency relation between size and number of legs on the one hand and size and weight of body on the other. The maximum successful land animal would appear to be the elephant. The reason why the brontosaurus was not a success is probably due to two factors: unwieldy size of body and smallness of brain. It spent most of its time in the water possibly because the buoyant nature of the water made life easier.

Then we have the role of water in fertilisation. It is very noticeable that although millions of years have elapsed since many of the ancestors of animals living today left the water for the land, they still depend on water as a transporting medium in fertilisation. In some cases, as in many amphibians, recourse is made to water by males and females at the mating season and the process of fertilisation takes place in water. In mammals, the fertilisation of the ovum in the female is caused by the impregnation by a sperm, but the whole process is enabled to take place through an aqueous medium, the spermatozoa literally swimming in the direction of the ovum.

The next subject for consideration is the role of water in diffusion and osmosis. These are often considered in regard to plants, but it must not be forgotten that they take place in animals as well. It is important to make the distinction between diffusion and osmosis clear. In diffusion, the membrane does not exert a selecting power. It is a process by which gases and liquids penetrate a partition of some kind. In osmosis, the membrane causes selection. This membrane is referred to as a semi-permeable membrane because of this selectivity. Such a membrane allows an ionised solution to pass, but prevents the flow of a colloidal or un-ionised liquid or solution. Diffusion and osmosis are usually brought in to offer an explanation as to how salt solutions get into the plants from the soil. The subject is, however, rather complex and the explanation is probably not fully understood.

Closely linked with diffusion and osmosis in the plant, are root pressure and transpiration. The movement of solutions up the plant from the root to the topmost portion is thought to be due to all four effects. Various experiments can be carried out to show the effects even though a full explanation cannot be given.

Lastly reference should again be made to transfer of power. This was previously considered in regard to fire. Water is usually the medium through which power is transferred. It is sometimes transferred through water in the liquid form as in hydraulics employed in lifts and the turning of bridges. There is a tendency in many cases to use oil in place of water as in a hydraulic jack. Where tremendous and continuous power is required the water is converted into steam and the energy locked up in the steam is utilised in steam engines and turbines. This energy is made more adaptable and useful at a distance by using the engine or turbine to drive an electric generator.

THE UTILITY SERVICES: WATER, GAS, ELECTRICITY AND WIRELESS

A large part of a syllabus can be centred round the utility services, in which I include Water, Gas, Electricity and Wireless. In chapter 2, *section* A(1), I have dealt at some length with water and in chapter 10, section H, I have briefly considered wireless. The other two might be dealt with somewhat as follows:—

Gas

1. An examination of the destructive combustion of paper, wood and coal to show the formation of the inflammable gases.

2. A visit to the gas works.

3. The making of a model gas works that will produce purified gas.

4. How the composition of coal gas is related to its functions.

5. Appliances using coal gas.

Electricity

1. Brief historical account of electricity and its development beginning with Oersted and Faraday.

2. The making of a model dynamo.

3. Methods of driving a dynamo: steam engine, steam turbine, water turbine.

4. Alternating and direct current.

5. Solenoids and electromagnets.

6. The principle of the electric bell.

7. The transformer.

8. The Grid System.

9. The wiring of a house.

10. The principles of electric appliances depending on the heating effect, e.g. electric fire, electric iron, hot plate and electric oven.

11. The principles of electric appliances depending on the electric motor, e.g. vacuum cleaner, fan.

12. Electric lighting. The evolution of the electric bulb. Direct, indirect and semi-indirect lighting. Fluorescent lighting.

14. The electrical system of a modern car: Ignition, starter motor, dynamo, accumulators, lighting, trafficators, windscreen wipers.

THE BIOLOGY OF FOOD
(OUTLINE)

A.

This may be begun with a statistical analysis of the school meals subject to the approval of the School Governors. Such an analysis can be done by first of all obtaining the following data:

1. No. of meals served over a representative period of say four weeks. These need not be consecutive.

2. Quantities and kinds of food eaten during this period. By means of a good table of food values, it is roughly possible to calculate the numerical values of such factors as calories, proteins, Vitamins, iron and calcium in the food which the children consume.

By dividing the total quantities of these food factors by the number of meals we arrive at figures for an average meal.

This was worked out in the author's school and gave the following result:

Table 9. Amounts supplied *per child* each *mid-day meal.*

Protein	27 gm.
Calcium	241 mg.
Iron	4 mg.
Vit. A	2196 i.u.
Vit. B	182 i.u.
Vit. C	3.7 mg.
Calories	492

i.u. = international unit

It is interesting to compare this table with a table for the average adult requirements for one day.

Table 10

Protein	70 gm.
Calcium	800 mg.
Iron	12 mg.

Table 10—contd.

Vit. A	5000 i.u.
Vit. B	600 i.u.
Vit. C	50 mg.
Calories	3500

Table 11. Table giving percentage of daily requirements supplied in the School Meal

Protein	39
Calcium	30
Iron	33
Vit. A	44
Vit. B	30
Vit. C	8
Calories	14

B.

The second stage of the work is to show in what ways errors creep into this analysis. The chief errors are of two kinds.

1. We are not sure how far the cooking depreciates the food values. These are affected to different degrees. We might devise experiments to show this. For example, the calorific values of raw and boiled potatoes may be compared.[1] This loss may be studied along with the loss in Vitamin C which can be fairly easily measured by a titration method.[2]

2. The same meal does not necessarily affect children in the same way. This leads on to the chemistry of digestion. Simple experiments can be carried out to show the effects of the various digestive enzymes.

C. Tests for Fats, Carbohydrates, Proteins, and Vitamins

Children can carry out simple experiments to show how we can identify fats, carbohydrates, some proteins and some mineral salts. Apart from Vitamin C, it is too difficult to show experiments demonstrating how we identify the

Vitamins. It may be possible with A children in their last year to indicate to them the biological methods and the spectrographic methods of identification.[3]

D. The Formation of Foods

This is an interesting subject which is often entirely missed. Foods come from many sources: plants, animals and minerals, and all these sources are necessary. It can be shown how plants during photosynthesis initiate the process whereby fats, carbohydrates and proteins are produced not only in plants but also in animals. The animals eat the plants converting the fats and carbohydrates into energy and breaking down the proteins preparatory to rebuilding proteins needed in the animal structure. Most of the mineral salts are obtained indirectly from plants and animals as food, but there is the notable exception of common salt.

E.

If science is included in social studies it may be possible to consider the history of food. This may include the following aspects:

1. The improvement of the quality and the quantity of foods throughout the ages.
2. The increase in the availability of food to the masses of the population.
3. The problem of feeding Britain in the last war.

References (Appendices)

[1] Chapter XIII: P. M. Mitchell, *Biochemistry* (McGraw & Hill Book Co.). 1946.

[2] L. J. Harris and M. Olliver, *Biochemical Journal*, 1942, 36, 155.

[3] M. R. Rosenberg, *Chemistry and Physiology of the Vitamins*, New York. 1942.

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